Establishment of an integrated water quality monitoring framework for Georges Bay

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Executive Summary

- This report summarises the water quality information available for Georges Bay. Data have been collected by a variety of groups, using different methods and measuring different variables over varying time periods. As a consequence, the water quality of Georges Bay has not been systematically assessed. A water quality monitoring framework for Georges Bay is clearly needed.

- From the limited information available, the bay appears to be in reasonable health. Nutrient concentrations were mostly low, no herbicides or pesticides were detected in the water or animal flesh, chlorophyll a values were generally below bloom conditions and seagrass and fish populations, which are recognised indicators of environmental condition. are indicative of a healthy estuary.

- However, most water quality sampling has been conducted during normal conditions, and limited data collected during flooding indicates significant deterioration of water quality during and after these events.

- The results show that the current sewage treatment system is periodically not meeting acceptable standards, especially after flood events. There also has been no monitoring of stormwater outflow since 2001 and substantial development has occurred since then. It is recommended that storm water outflow is monitored, especially during and after significant rain periods.

- The difference between community and expertise-based monitoring is discussed and the requirements for the two types of monitoring are detailed. A coordinated monitoring program which includes monitoring by local council, community groups and State Government agencies is essential to maximise the financial and human resources available for monitoring. The data should be held in a centralised database, with standard quality assurance procedures, and readily accessible to stakeholders.

- The indicators recommended for monitoring the health of the Bay are based on the Waterwatch National Technical Manual, especially Module 7 on community estuarine monitoring (to be released in October 2005) and on the recommendations of the Tasmanian Coastal, Estuarine and Marine Indicators Working group, a group of experts developing a list of indicators to standardise estuarine and marine monitoring around Tasmania. These are summarised in Table (i) below in relation to Georges Bay, showing the list of parameters required for baseline and ongoing monitoring, frequency of sampling, and the suitability of indicators for community and expertise-based monitoring.

Table (i) Recommended monitoring program for Georges Bay. The availability of baseline information is included.

Monitoring program for Georges Bay

Parameter	Baseline data	Ongoing monitoring	Event monitoring	Community monitoring	Expertise monitoring
Temperature	yes	monthly or automatic	yes	yes	yes
Salinity	yes, limited profiling	monthly or automatic	yes	yes	yes
Turbidity	no	monthly or automatic	yes	yes	yes
Dissolved oxygen	no	monthly or more frequent	yes	yes	yes
pH	no	monthly	yes	yes	yes
Chl a	some	monthly	yes	?	yes
algal blooms	no	monthly, if funds available		yes	yes
NOx, NH4, PO4	some	monthly	yes	?	yes
TN, TP	some	monthly, if funds available	yes	?	yes
seagrass bed area	yes	annual	no	yes	yes
seagrass condition	yes	annual	no	yes	yes
invertebrates	no	1+years	no	no	yes
intertidal algae	no	seasonal	no	yes	?
saltmarsh area	no	annual	no	yes	yes
bacteria	yes	monthly	yes	?	yes
animal kills	some	when occurs	yes	yes	yes
toxicants	some	determined annually	yes	no	yes
shoreline position	no	?	?	yes	yes

- A template for annual assessment of the condition of Georges Bay was developed, based on criteria established by the Moreton Bay Catchment Water Quality Management Strategy Team (1998) for their Report Card reporting system for stakeholders in Moreton Bay. A mark from A to F can be assigned to Georges Bay, with ‘A’ being the highest, where the area has an ecological system that is productive and is balanced. ‘F’ is a failure, where the natural system is not functioning well and there is little or no biodiversity.

- Using these criteria and information on the severity of degradation in several sections of Moreton bay, a report card was prepared for Georges Bay for the twelve months July 2004 to June 2005 (Table (ii). Georges Bay is given a 'B' rating, based on the data available. The Bay has healthy seagrass beds, nutrient concentrations are mostly low, although can reach high levels on occasions, no toxicants have been observed in water or oyster flesh samples and bacterial levels in the estuary are low. However, some nutrients and bacterial levels in the Georges River entering Georges Bay are high and stormwater outfalls have BOD and pH values outside the guidelines. The periodic mortality occurrences of farmed oysters in Moulting Bay is also cause for concern. A more precise classification of the health of Georges Bay would be possible if more data were available on recommended environmental parameters.

- A major challenge for stakeholders of Georges Bay will be to secure the resources required, both financial and human, to complete the baseline assessment and to continue monitoring. The community, Break O'Day Council and State Government will need to work in close cooperation and all contribute to the process so that sufficient resources are available to routinely assess the condition of the Bay. This is essential to maintaining the exceptional natural assets of Georges Bay and the sustainability of the Bay community.

Table (ii) Report card for Georges Bay, July 2004 to June 2005

Report card for Georges Bay: for 12 months July 2004 to June 2005

Parameter	Comments	Ranking*
Temperature	normal	1
Salinity	normal	1
Turbidity	limited data	
Dissolved oxygen	no data, BOD above guidelines at sewage outfall	
pH	limited data, mostly within limits except at sewage outfall	
Chl a	no data	
Algal blooms	limited data, no toxic algal blooms	
NOx, NH4, PO4	NOx - few high values especially Bridge site, NH4 - mostly low, no PO4 data	3
TN, TP	TN - sites in Bay occasionally > WQT, Bridge site ≥ WQT; TP - sites in Bay often > WQT, Bridge site low	3
Seagrass bed area	increased since 1990, stable since 2001/02	1
Seagrass condition	baseline data, limited seasonal data, good condition	2
Invertebrates	no data	
Saltmarsh area	no data	
Pest species	no data	
Bacteria	low in estuary, high at Bridge site	2
Animal kills	ongoing low level oyster mortalities, no mortalities of native species	3
Toxicants	no chemicals above detectable limits in water or oyster meat samples	1
Shoreline position	no data	
Other events of note	none	

*Ranking: 1=excellent, 2=good, 3=satisfactory, 4=poor, 5=degraded

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Terms of Reference

The Terms of reference for this report which were agreed to by the Tasmanian Aquaculture and Fisheries Institute and the Break O'Day Council are as follows:

- To collate existing water quality data within Georges Bay and recommend integrated collection arrangements. This will include data at key input points, for example, Georges River and storm water outfalls.
- To assess data quality and develop and advise on necessary QA/QC measures particularly in relation to identified water quality threats to Bay.
- To establish a yearly reporting mechanism protocol to report to the community findings on the Bays water quality and implications of findings.
- To recommend an integrated response protocol where adverse water quality findings are identified
- To advise on ways of linking information through State water quality information management systems eg TSQAP, DPIWE, Council, Northern NRM
- All work should compliment the work of Georges Bay Study being undertaken by TAFI.

Introduction

Background

Georges Bay is located on the north east coast of Tasmania and is a relatively large coastal estuary, with a surface area of approximately 18.4 km^2 (Crawford & Mitchell, 1999). The estuary is open to the Tasman sea through a long narrow entrance and extensive system of sand bars. Georges Bay is fed by a number of rivers and creeks, the largest being the George River, which has an average discharge of 6 m^3/s at Priory (WIRED, 2005) and a catchment area of approximately 614 km^2 (DPIWE, 2005). St Helens is the major settlement in the area, being located on the western coastline of Georges Bay.

The climate of Georges Bay is temperate maritime, varying from a mean of 11.9-23.0^oC in Febuary to 2.5-13.8 ^oC in July. Rainfall tends to be sporadic, although minimum rainfall generally occurs in summer, and maximum in winter. Occasional very high rainfall events occur on the east coast, affecting Georges Bay. The last of these events occurred on the 27th-30th January 2004, when 234 ml of rain fell in St Helens and 284 ml in the upper catchment at Pyengana (TSQAP, 2004). This lead to a flooding of the St Helens township and contributed to a loss of $1.6 million to the oyster industry.

Geologically, the Georges Bay catchment area is comprised predominately of granitic rocks with patches of quartzose sandstone and scattered occurrences of basalt, mainly on hill tops (Bird, 2000). The George River is the primary watercourse, originating from two upper branches, the North and South George. These originate at an elevation of about 800 m in the Rattler Range at the western end of the basin and join near Pyengana. The George is also joined by the Ransom-Groom river system near Goshen, which originates in the Blue Tier Range on the northern side of the catchment basin (Bird, 2000). There are four major floodplains located at Pyengana, Goshen, Priory and the George River delta. The river negotiates these floodplains, holding a predominantly western course, entering Georges Bay on the north-west shore (Fig. 1).

The form of Georges Bay is complex, incorporating two smaller secondary embayments, being Moulting Bay to the north and Medeas Cove in the southwest. Moulting Bay is a shallow offshoot with extensive mudflats and contains the majority of the Georges Bay oyster leases. Medeas Cove is a much shallower embayment, located near the main township and is fed by the heavily silted Golden Fleece Rivulet.

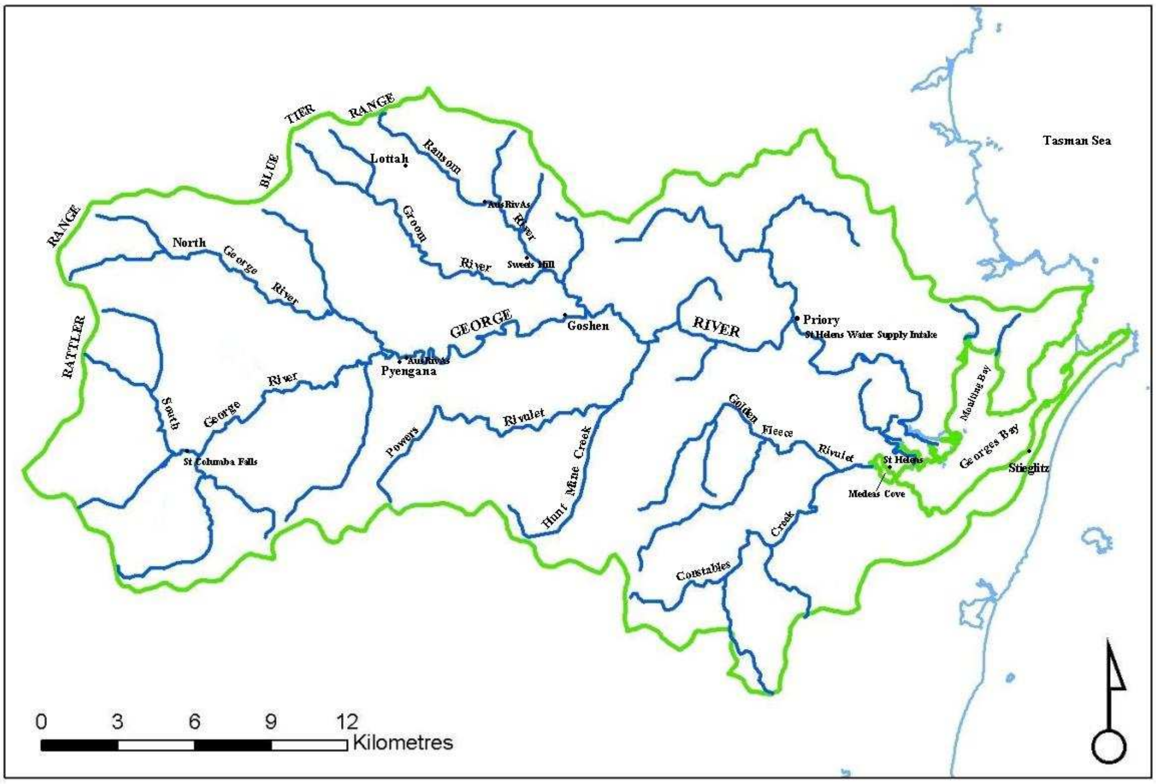

Figure 1. Map of Georges Bay catchment

The hydrodynamics of Georges Bay show a high tide volume of around 115 million m^3 and a tidal prism of approximately 12 million m^3. The Bay has a flushing time of approximately 10 tidal cycles, with tidal velocity increasing substantially near the shallow narrow entrance (Crawford & Mitchell, 1999). Water depths in Georges Bay are at their greatest in the wider upper reaches of the Bay, where they exceed 25 m. In contrast, water depths in Moulting Bay are rarely greater than 4m and the mean tidal velocity quite low, with an average of around 1 cm sec^{-1}. When Georges Bay is in flood tide, water flows across the entire bay except in the Humbug Point area, where water moves out of Moulting Bay and into Georges Bay proper. During an ebb tide water tends to move in a circular pattern out of Moulting Bay and flowing along the western shore out of Georges Bay, except in the Humbug Point area, where water moves along the eastern shore (Crawford & Mitchell, 1999).

The human history of Georges Bay began with the Aboriginal people who lived, hunted and fished in the area. The fertile nature of this land is reflected in the sedentary nature of the Georges Bay tribe. In the 1830's the first settlers, predominantly sealers and whalers, moved into Georges Bay and gradually over the next seventy years, several industries were established out of the Georges Bay area.

Farming began on the Blue Tier penninsula in the mid 1800s and initially it was a very tough existance. The timber industry was established at around the same time, supplying high grade sawn logs and joinery to the people of the Georges Bay district. Not long after, tin mining was established in the region following the discovery of tin at the foot of the Blue Tiers and this industry boomed. The Anchor Mine, on the headwaters of the Groom River near Lottah, was the most productive, operating almost continuously between 1885 and 1945. Between the mid 1880's and 1929 when stricter controls for the disposal of tailing were introduced, Bird (2000) estimates that approximately 1.2 million m^3 of sediment was deposited on the Goshen floodplain, with smaller amounts at Priory and the George River delta. These floodplains were choked with sediments, elevating bed level and causing increased over-bank flooding and deposition (Sprod, 2003).

The fishing industry, which still exists today, began from humble beginnings where 5 metre sail vessels precariously navigated the St Helens barway. Fish were then flown to the Melbourne fish markets. Scallops were discovered off St Helens in 1974, although these were quickly fished out, with a similar story for Orange Roughy. Abalone and crayfish are still fished from St Helens, although tourism is now opening up a new market in game fishing.

The towns of St Helens and Stieglitz were first surveyed in 1855, although Stieglitz was originally surveyed on the opposite side of the Bay to where it exists today. Initially, St Helens was just a port area, servicing the tin mining and timber industries. The first major anthropogenic impact into the Bay was the major silting of waterways from mine tailings following the floods of 1929. This resulted in much of the upper reaches of Georges Bay being lost, and many other sections of the Bay impacted upon (T. Walker, BODC, pers comm). For example, when originally surveyed by Brooker in 1862, Medeas Cove was reported to have water depths of up to 18 feet (5.5 m) deep. By the 1920's, Medeas Cove was reported to have extensive mudflats, and since then each major flood event has bought addition sediment load. Today, flows tend to move through, rather than over the tailings (Bird, 2000).

The first waste water disposal system was implemented following development of St Helens in the mid 1900s. This system collected stormwater, sullage and septic tank effluent and piped these wastes directly into the Bay. This remained in place until the early 1980s, when the present sewage lagoon system was constructed. Since then, ongoing works have been confined to upgrading the sewer system. There exist small pockets of the Georges Bay area that are not serviced by the sewer system, although Break O'Day council has a program to service all accessible properties in St Helens and Stieglitz, including Akaroa (T. Walker, BODC, pers comm).

Due to concerns regarding quality and quantity of effluent released into the Bay, Break O'Day Council is proposing to upgrade the current lagoon system to Membrane Bio-reactor technology. This technology allows for the production of high quality effluent, which requires no primary or secondary settlement stages and will be supplemented by UV treatment (SKM, 2005). The existing lagoons will be maintained and used as emergency storage. In the future, Break O'Day Council hopes to incorporate the Stieglitz treatment system into this facility.

In terms of conservation significance, Georges Bay was given Class D ranking by Edgar et al. (1999). Estuaries across Tasmania were classified according to conservation significance based on factors such as level of human disturbance and percentage of catchment area protected. Class D is an estuary of low conservation significance, meaning that the estuary and associated catchment have been moderately degraded by human impacts. Edgar et al. (1999) recommended that Class D estuaries should be made available for a variety of recreational and commercial purposes, and remediation processes should be assisted where practical.

At present Georges Bay is used for a variety of purposes including tourism, local recreation, aquaculture and fishing industries. Water quality in the estuary is very important to a number of these groups. For instance, the ecosystem must be healthy enough to allow industry to harvest various fish and shellfish, as well as allow recreational users to engage in activities such as swimming and boating.

Protected Environmental Values (PEVs) have recently been finalised for Georges Bay. These PEVs are for (A) Protection of aquatic ecosystems – protection of modified (not pristine) ecosystems from which edible fish, shellfish and crustacean are harvested, (B) Recreational Water Quality and Aesthetics – primary contact water quality, secondary contact water quality, aesthetic water quality and (E) Protection of Aquaculture Species`

Identified Water Quality Threats

At present there is no clear integrated water quality monitoring framework for Georges Bay. Numerous groups have conducted water quality monitoring on Georges Bay and the catchment region, including stakeholders, research institutions, community groups and local and state government departments (see Fig. 2 concept map). There have been numerous reports published by these groups aiming to identify clear water quality threats. For a summary of these reports see see Appendix 1.

The George River is believed to be the largest potential source of pollutants, particularly in times of flood. Thus, health of the George River is critical in maintaining the health of Georges Bay. The pattern of freshwater dispersion within Georges Bay is variable. In normal flow conditions dispersal is dependent upon wind direction and speed, freshwater inflow volume and tide (TSQAP, 2003). Pollutants transported into the Bay include high levels of bacteria, as well as suspended matter including fine sediment, detritus and organic material.

The history of mining in the Georges Bay catchment has also had an impact on the water quality of the Bay. Water quality can be affected directly by historic tin-mining operations through the continued generation of acid drainage from exposed sulphide-rich rocks (Koehnken, 2001). However, indirectly, the release of large volumes of sediment has had a large impact on the flow and form of the George River. Coupled with deforestation and agricultural clearing around the early 1900s, flooding has been more destructive, with the George River delta now over one kilometre wide and containing multiple active braided stream systems. Whilst the George River appears to be self-remediating over time (Bird, 2000), the Golden Fleece Rivulet and Medeas Cove may never recover from the sediment loading.

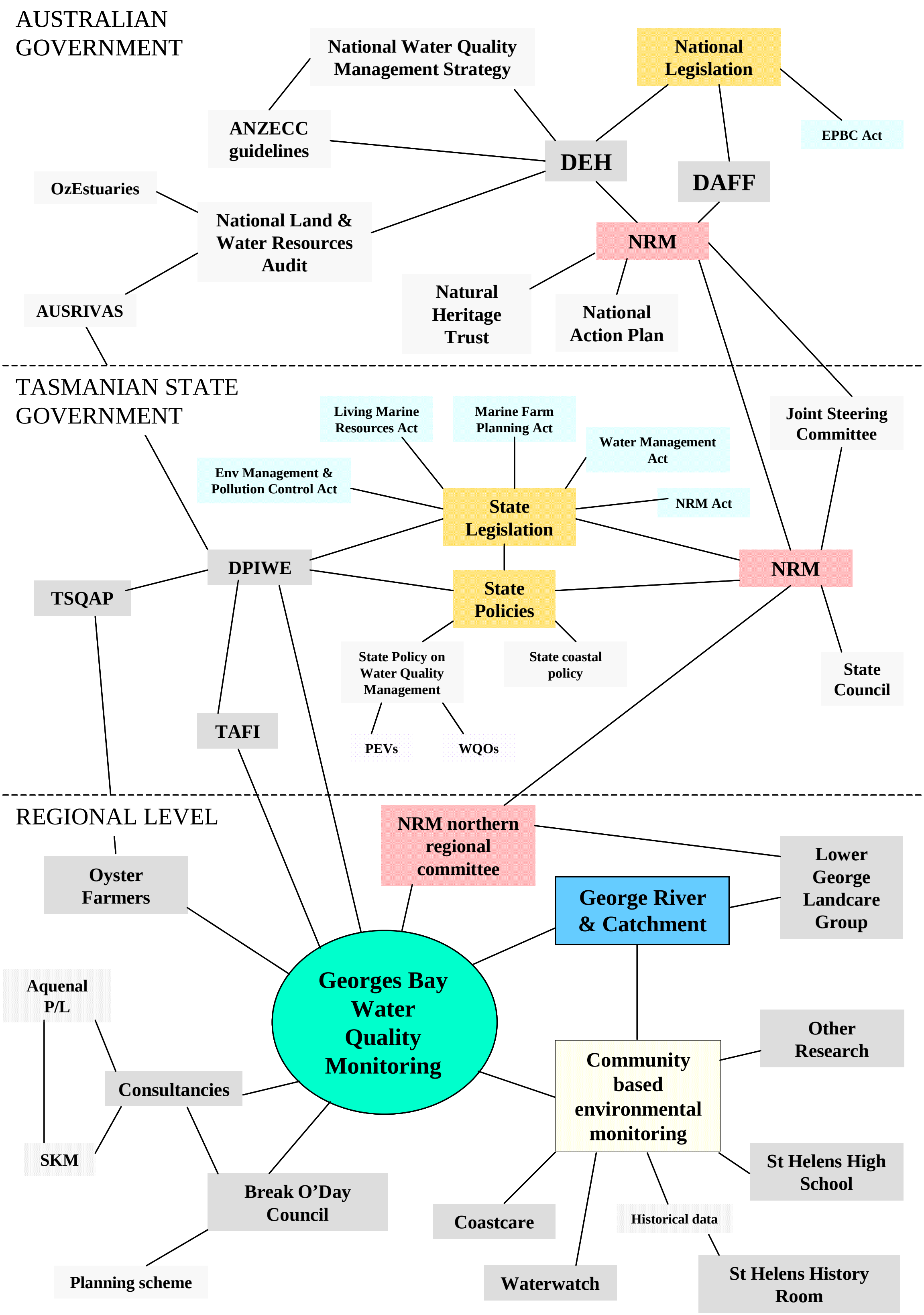

Figure. 2. Concept map of water quality monitoring in the Georges River and Georges Bay

The bathymetry of Georges Bay has been altered by the influx of sediments since the commencement of mining in the catchment. The mouth of the George River appears to have changed significantly, with sand and fine silts burying the extensive mudflats that were present in the 1800's. From aerial photography Sprod (2003) estimates that by 1998, 0.4 million m^3 of tailings had been discharged into Georges Bay. It is likely that there is still a considerable volume of sediment held up in the catchment, with the potential to be released into the Bay. This continual sediment loading may be influencing water quality variables in the Bay, such as turbidity, sediment composition, benthic infaunal communities and distribution of sea grass.

Recently, pesticides and herbicides from forestry, small crops and horticulture operations have caused concern within the local community as potential pollutants in the catchment, particularly following periods of high rainfall. Several chemicals used in forestry and farming activities do have the potential to affect biota should sufficient concentrations reach the George River as run-off or in flood events (Percival, 2004). At this stage there is a lack of knowledge regarding the possible effects of extremely low levels of pesticides and herbicides on an ecosystem.

Tributyl-tin (TBT), a toxin found in some anti-fouling paints, has also been identified as a potentially significant threat to the health of the Georges Bay ecosystem and shellfish aquaculture industry (Koehnken, 2001). TBT can have adverse effects on survival, growth and reproduction, and is also known to cause imposex (females exhibiting male characteristics) in molluscs (see Horiguchi, 2005; Evans et al., 1995; Kohn & Amasi, 1993). The use of TBT paints in Tasmania was discontinued by Ministerial order in December 2001, except by way of a permit (Noller, 2003) and was banned for sale in 2003. TBT has been investigated and reviewed extensively since early 2001.

The water quality of Georges Bay is also influenced by other inputs such as sewage discharge and stormwater runoff. Historically, seepage from septic tanks probably had a large impact around the Bay. However, upgrades to the sewer system have improved this situation considerably, with wastewater from households being treated before release. The sewage outlet pipe from the St Helens wastewater treatment plant discharges into Georges Bay, creating a point source of pollution. Release of untreated sewage from the sewerage treatment plant occurs occasionally in association with heavy rainfall (Percival, 2004). Whilst the current system is quite functional, the effluent discharge quality is of minimum standards. Emissions are frequently over draft guideline values set by DPIWE (2001). As a result of the expansion of the aquaculture industry in the Bay and concerns regarding water quality, Break O'Day Council is proposing to upgrade the system. In heavy rainfall, there is also a significant amount of stormwater entering the Bay. Stormwater contamination may transport a large amount of pathogenic organisms, as well as litter, oils, heavy metals and other urban contaminants, and consequently may impact the health of Georges Bay.

The remainder of this section summarises the major reports relevant to the water quality of Georges Bay. These reports provide useful information on the current water quality of Georges Bay and will aid in the establishment of an integrated water quality monitoring program.

Oyster Health in Georges Bay – Collation and analysis of data (Percival, 2004)
This report was compiled in response to concerns by oyster farmers regarding an increase in oyster health problems. It includes a comprehensive collation and analysis

of historical data, including water quality information. The report suggested that there was no apparent single cause of oyster health problems in Georges Bay. Instead, the report cited numerous factors that may have the potential to contribute to oyster health problems, such as:-

- Extended periods of low salinity
- High turbidity impacting on phytoplankton abundance, speciation and oyster feeding rates
- Toxic phytoplankton
- Contamination of water by forestry, industrial, urban and/or agricultural chemicals
- Contamination of sewage

The report also made recommendations for future investigations such as:-

- The development of a structured, cooperative and coordinated approach to future investigation, including as many stakeholders as possible
- Linkage with the Natural Resource Management (NRM) project being coordinated by the Georges Bay Water Quality Committee
- Targeted investigation program comprising of an initial broad scale pilot program including an audit of chemical usage in the George River catchment, followed by a more focused ongoing project
- Preparation for timely structured investigation of flooding events
- Collection of appropriate and uniform production data by oyster farmers
- Research trial investigating the effects of salinity, temperature and suspended solids on oyster health
- Investigation by farmers of ways to minimise stress at handling and during flood events
- Seek to remedy any unacceptable inputs into Georges Bay and the catchment area

Environmental Problems, Georges Bay, Tasmania (Scammell, 2004)

Similar to Percival (2004) this report investigated the mortality of commercial oysters in Georges Bay, focusing on the losses that occurred following the February 2004 flood event. This report presents arguments that this amount of rainfall alone could not be responsible for mortality in oysters and other intertidal and subtidal species. The report details the crash of a forestry helicopter in the Georges Bay catchment prior to the flooding event. The helicopter was carrying a 29 kg payload of alpha cypermethrin, a biocide that is toxic in aquatic ecosystems. The report investigates the link between the two events and the reasons behind such findings.

DPIWE response to the Scammell report (DPIWE, 2004)

A strong case was presented that challenged many of the assumptions and findings of the Scammell report, including scientific evidence suggesting that Pacific oyster are relatively insensitive to cypermethrin. This report also indicates that alpha cypermethrin binds strongly to soils and clays and is not very mobile in the environment. Hence, the DPIWE response considers it unlikely that pesticides released from the helicopter crash in the Georges Bay catchment was the main cause of oyster mortalities following the February 2004 flood event.

Lower George Rivercare Plan – Lower George Landcare Group, St Helens (Sprod, 2003)

This report defines the visions and goals for Lower George River. Their five strategies are:-

- Control of stock access to the George River system
- Control of crack willow in the riparian zone
- Enhancement of the recovery rate of the native vegetation
- Enhancement of the geomorphic recovery
- To define and address point source and diffuse pollution

It indicated that the catchment and river system are still recovering from extensive alluvial tin mining, although otherwise is in reasonably good condition. The three major flood plains (Goshen, Priory and the Delta) all still have relatively thick deposits of sediment, although the channel is actively down-cutting to its original bed level. This report also suggests that there is still substantial amounts of sediment within the river system.

Critical review of the environmental fate of TBT and its toxicological effect on the Pacific oyster Crassostrea gigas including at Georges Bay and other Tasmanian locations (Noller, 2003)

This report provides a review of the DPIWE sampling program to investigate possible TBT effects on the oyster lease productivity of Georges Bay. TBT levels were only elevated around slipways and wharf areas, and absent from oysters in the leased area. This agrees with the general finding overseas that there needs to be significant sediment concentrations and/or supply in the water column to produce observable effects on oysters. The report also cited other potential factors that could effect oyster health.

St Helens Sewage Treatment Plant Upgrade – Biological survey and impact assessment (Aquenal Pty Ltd, 2004)

This document presented a literature review and assessed the impact of the existing outfall pipe. Benthic infauna data collected reflected impacted communities in the vicinity of the outfall, with low level impacts at sites up to 200m from the outfall. However, as a result of improved effluent quality and increased dilution rates, the authors suggested that the zones of moderate and low impact for benthic species are likely to decrease following the treatment upgrade. This report also highlighted the need for an integrated water quality monitoring program, as long term data sets required for the establishment of baseline conditions were not readily available.

Physical and Chemical Parameters of Several Oyster Growing Areas in Tasmania (Crawford & Mitchell, 1999)

In an effort to determine carrying capacity for oyster farming, this study investigated the physical and chemical parameters of several areas, including Georges Bay. Valuable environmental data were collected, including hydrodynamic regimes, temperature, salinity, nutrients and chlorophyll a. Georges Bay is relatively productive compared to other estuaries, particularly considering the lower flushing rate of Moulting Bay. The input of nutrients from the George River and the sewage treatment plant were cited as possibly reasons for this productivity.

Management Plan for the Moulting Bay Growing Area, April 2003 (TSQAP, 2003)
This report by the Tasmanian Shellfish Quality Assurance Program (TSQAP) outlines the management strategy for each of the five shellfish lease zones in Georges Bay. All leases are classified as Approved Conditional, meaning they are subject to infrequent, predicable pollution events. The George River was reported by the authors as the most significant potential source of faecal contamination in the growing area. Consequently, the salinity of Moulting Bay is used as a proxy to determine the levels of faecal contamination in the water, with rainfall at Pyengana used to prompt salinity checks.

Water Quality Data Available

Water quality information for Georges Bay and Georges River has been collected by a variety of groups at a number of sites and over varying time intervals. Table 1 lists all the water quality studies that we have been able to find, site locations, time period of sampling, environmental variables measured, type of data and who holds it. Appendix 1 provides more detailed information on most of these studies and others of relevance to water quality in Georges Bay. If there are other relevant environmental data for Georges Bay that we have missed, we would appreciate receiving this information to add to the database that we have developed.

Table 1 - List of water quality and related studies conducted in Georges Bay and Georges River

STUDY	SITE	TIME PERIOD	VARIABLES MEASURED	DATA TYPE/ QUALITY	HELD BY
Environmental Monitoring Data	Georges Bay (23 sites)	January 1983 - present	Temperature, salinity, tide, wind direction, faecal coliforms, rainfall (St Helens &Pyengana).		TSQAP
Monitoring of Algal species	Moulting Bay	July 2001 - March 2005	Algal taxa	Includes some full counts	TSQAP
Growing area data evaluation	Moulting Bay oyster leases	Annually 1992 - present	Heavy metal, pesticides & herbicides in oyster meat, salinity, rainfall, faecal coliform & marine farm status	Annual data summaries	TSQAP
Recreational Water Reports	O'Connors Beach, Steiglitz Beach, Beauty Bay	Annually *** - present	Thermotolerant coliforms & enterococcus		Break O'Day
Sewage outfall sampling	St Helens sewage outfall	Continously over monthly, 3 monthly & 6 monthly periods	BOD, NFR, faecal coliform, conductivity, pH, dissolved oxygen, oil & grease		Break O’Day
Stormwater sampling	Kirwan Beach, Lawry Heights & Jason St outfalls	2001 (x4 sampling runs)	Total coliform levels		Break O'Day
Pesticide/Herbicide sampling	Priory on the George River & Tap Water	July 2004 - June 2005	Agricultural & forestry chemicals		Break O'Day
Physical & Chemical Parameters	Georges Bay - Marine, Redflash, Lord's Pt, Humbug & Mast	April 1993 - Feb 1994	Temperature, salinity, chlorophyll a, NOX, NO3, NO2, PO4 & SiO4		TAFI
Survey of *Undaria pinnatifida* in Georges Bay	Lords Point, midway between Lords Point & Humbug Point, and Humbug Point, marinas, slipways & boat ramps	4th August, 2004	Density along transects, presence/absence at marinas, slipways & boat ramps	Quantitative transects, qualitative observations	TAFI
Habitat assessment for Commercial Finfish	Georges Bay - Mouting Bay Nth, Moulting Bay SW, Steiglitz Beach & McDonalds Pt	Seasonally Feb 1995 - Feb 1996	Commercial finfish - life history stages.		TAFI
Benthic sampling	Oyster lease in Moulting Bay	Jan & Feb 2000	Current speed & direction, sediment particle size, sediment deposition, redox, sulfide, oganic carbon, turbidity & benthic infauna		TAFI

Benthic sampling	Three transects in Georges Bay perpendicular to shore	Once off, November 1996	Benthic infauna, sediment size, salinity		TAFI
Continuous water quality monitoring	Continuous monitoring station at Priory (St Helens water supply uptake)	Ongoing from November 2004, hourly for flow, monthly for other variables	Flow rate, total phosphorus, dissolved phosphorus, dissolved oxygen, total nitrogen, dissolved ammonia, nitrates, conductivity, turbidity, pH and stream level	Continuous long term data for flow	DPIWE
George River water quality data	Priory (St Helens water supply intake)	?	Temperature, conductivity, pH, colour, suspended solids, filt, dissolved oxygen, Cu, Mg, NOx, NH4, orthophosphate, PO4 and coliforms	Averages for long term dataset	WIRED on DPIWE website
George River stream gauge data	Priory (St Helens water supply intake)	Apr 1968 to Oct 1990	Flow rate		WIRED on DPIWE website
George River stream guage data	Ransom River at Sweets Hill	Feb 1983 - present	Flow rate		WIRED on DPIWE website
Pesticide/Herbicide sampling	Priory (St Helens water supply intake)	4^{th} Feb 2004 – present (ongoing)	Agricultural & forestry chemicals		DPIWE
George River & catchment assessments	George River at Pyengana, Nth George River at the Tasman Hwy, Sth George River at St Columba Falls, Groom River at Anchor Rd, Powers Rivulet at Terryvale Rd and the Ransom River at Murdochs Rd	Intermittently 1994 - 2004 in spring & autumn	Temperature, conductivity, pH, turbidity, dissolved oxygen & macroinvertebrate fauna		DPIWE (AUSRIVAS)
Geomorphology of the George River	Holocene delta, mouth of the George River	1864, 1950, 1998	Sediment deposition & geomorphic changes	Qualitative - aerial photography	Lower George Landcare Group
Water quality monitoring (George River)	Priory + seven smaller stations	Feb 98 - Dec 01 (+ infrequently at smaller stations)	pH, temperature & turbidity		Waterwatch
Water quality monitoring (Groom-Ransom River)	Groom River at Ransleys flat & Ransom River above Forestry Tas plantation + 16 smaller stations	Aug 98 - Nov 02 (+ infrequently at smaller stations)	Turbidity (+ temperature, pH, PO4, N-NO3, conductivity, dissolved oxygen & E.coli sporadically)		Waterwatch

Water quality monitoring (Georges Bay)	Medea Cove, Moriarity, Windmill & Jock's lagoon	Once-off or infrequently	pH, temperature, PO4, turbidity, N-NO3		Waterwatch
Water quality monitoring	Priory, stormwater outlet (Captains' Catch seafood) & St Helens tap water	Oct 2004 (x3 sampling runs)	Faecal coliform & heavy metals		St Helens High School & BOD Council
Marine pest surveys	3 wharf/slipway sites, 2 channel sites and 1 site at the breakwall at the Georges Bay entrance	May – Nov 2003	Habitat (diver mapping & video surveys), benthic infauna		Aquenal Pty Ltd/DPIWE
Benthic assessment	Proposed sewage outfall line	Nov 2003	Habitat (diver mapping & video surveys), benthic infauna		Break O'Day/Aquenal P/L
Benthic assessment	Marine farm development site – Hodgmans spit, east McDonalds Point, Moulting Bay east, sth-west Pelican Point	1999	Organic content, particle size, redox and infauna	Baseline surveys	Aquenal Pty Ltd
Water quality monitoring	Georges Bay – Lords Point, Mast, Bridge & Compass	Monthly ongoing since Nov 2004	Ammonia, NO_x, TN, TP, faecal coliform		SKM
TBT monitoring in Georges Bay	Slipways, wharf areas, oyster leases around Georges Bay	July 2001 – Nov 2002	TBT		DPIWE

Georges Bay – Health Assessment

Below environmental variables relating to water quality in Georges Bay are described using the results from the various monitoring programs and sole surveys that have been conducted in the Bay. Where possible, these results for Georges Bay are compared with those from other estuaries around Tasmania.

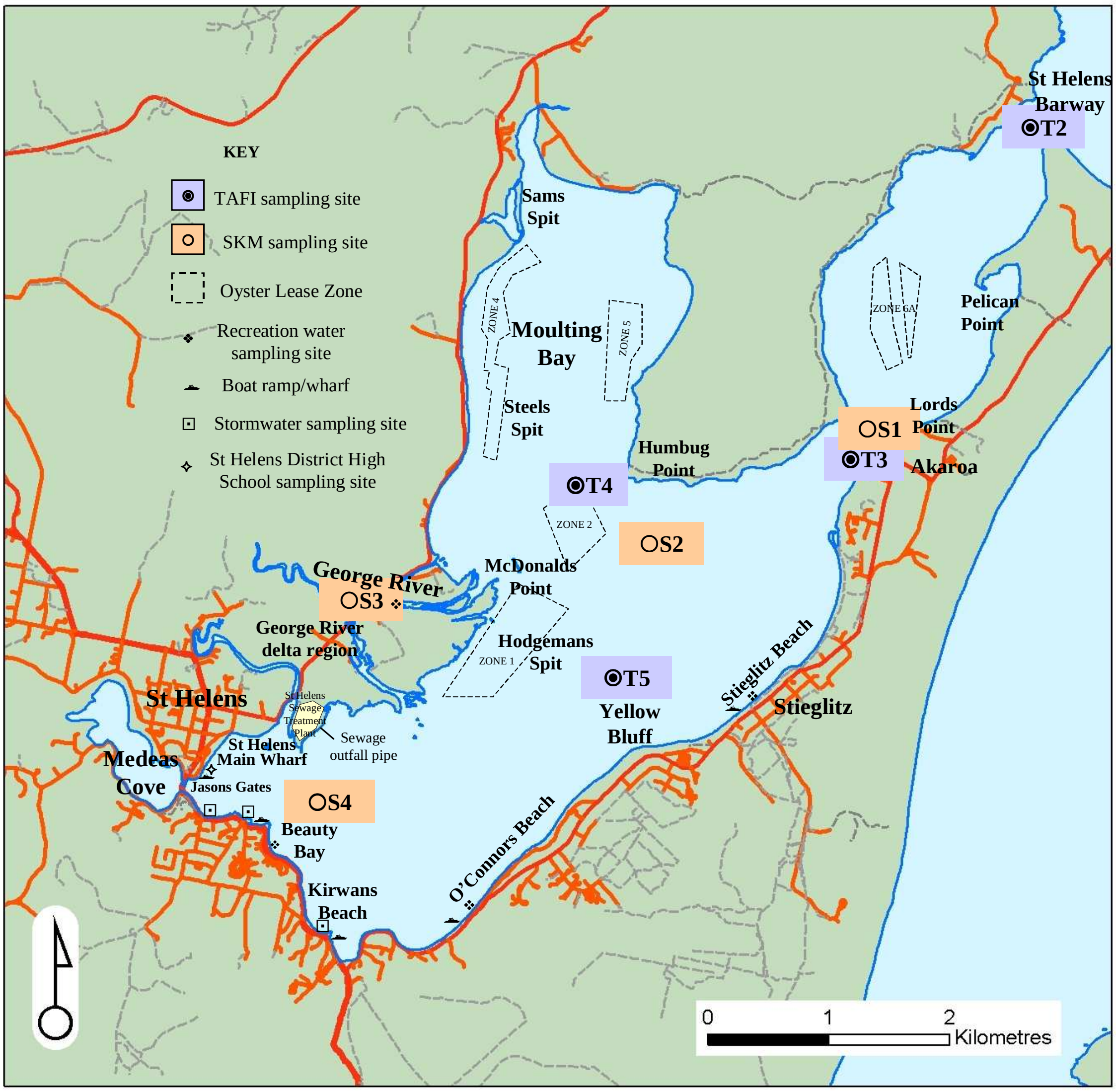

Figure 3. Map of Georges Bay including all relevant sampling points referred to the Georges Bay Health Assessment

Water Temperature

Water temperature of Georges Bay has been monitored in several surveys and studies. The most comprehensive long term dataset has been collected by the Tasmanian Shellfish Quality Assurance Program (TSQAP). TSQAP have monitored water temperature from January 1983 to the present.

Throughout this time period the annual average water temperature has not varied significantly (Figure 4), although sampling effort was not consistent throughout this time period.

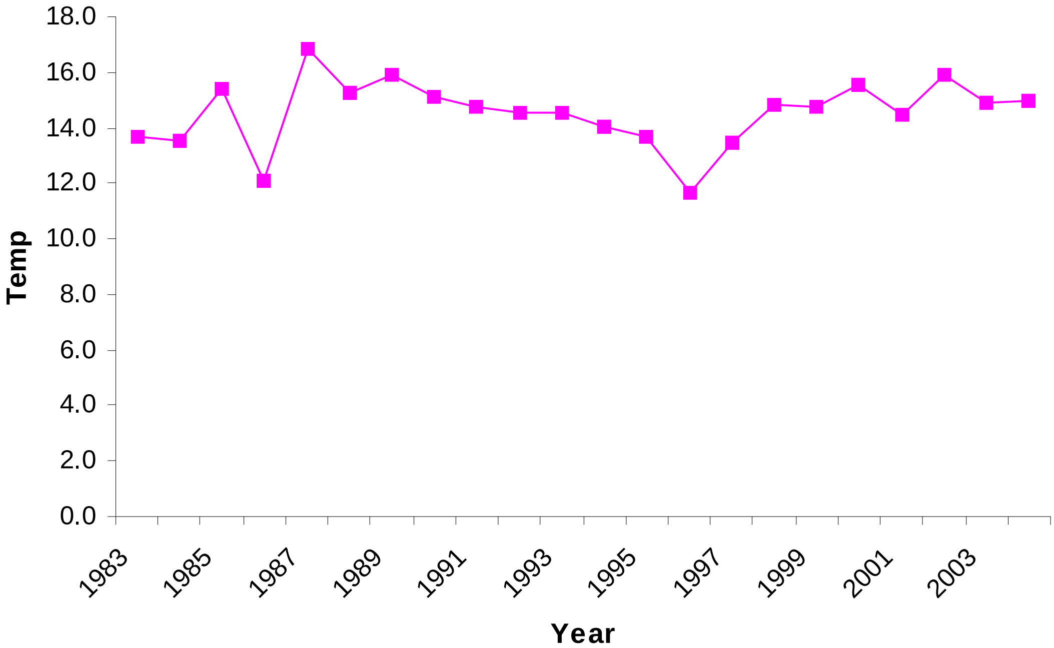

Figure 4. TSQAP average annual water temperature of Georges Bay (1983-2004)

The TSQAP dataset indicates that the water temperature of Georges Bay tends to range from 10.18 to 19.9°C annually (5th and 95th percentile). The highest temperature recorded was 23.8°C on March 14th 1999 and the lowest was 4.8°C on July 25th 1995. Mean monthly temperatures show a typical annual trend, with temperatures peaking around February/March, and the lowest temperatures recorded in winter.

Water temperature was also monitored as part of the TAFI study by Crawford & Mitchell (1999). Water temperature was recorded monthly from April 1993 to February 1994. A comparison of this data with mean monthly TSQAP temperatures for Georges Bay shows a very similar trend (Figure 5).

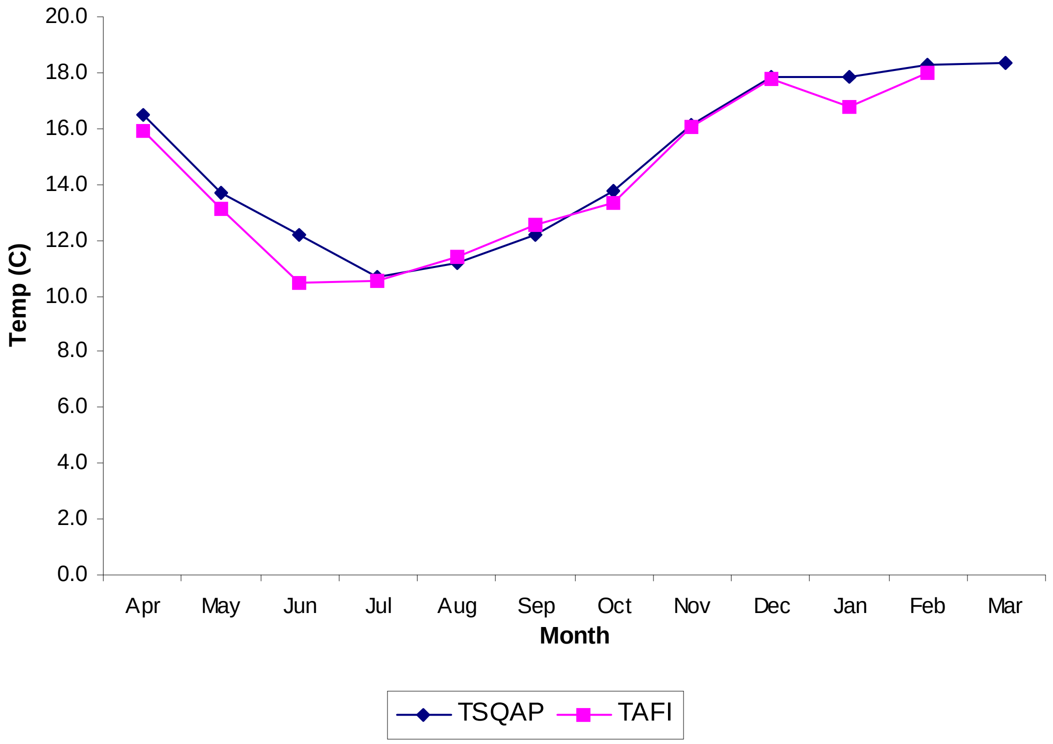

Figure 5. Monthly water temperature of Georges Bay

Similar temperature ranges have been recorded in estuaries along the east coast of Tasmania by Murphy et al. (2003). For example, Ansons Bay recorded an annual temperature range of 10.0-21.1°C and Grants Lagoon 10.1-23.8°C. Differences may be explained by the smaller volume and shallower nature of these estuaries.

Salinity

The salinity of Georges Bay has been closely monitored by TSQAP since 1983 to the present. Throughout this period salinities have been recorded ranging from fresh (0.0 ppt – May 20th 1983 from near the mouth of the George River) to saline (35-36 ppt, recorded frequently along the channel). TSQAP surveys are supplimented by data from a continuous data logger situated on an oyster lease near the mouth of the George River in Moulting Bay. The logger takes a record of temperature and salinity every hour, with thedata examined, then either saved or disgarded. The continuous logger data for 2000/2001 shows variable salinity levels throughout the course of a year (Figure 6), with low salinities being attributed to high rainfall. The TSQAP data also suggests an inverse relationship between rainfall and the salinity of Georges Bay, with the salinity strongly impacted by the flow of the George River. As part of their program, TSQAP monitor rainfall at Pyengana to trigger salinity checks in Georges Bay.

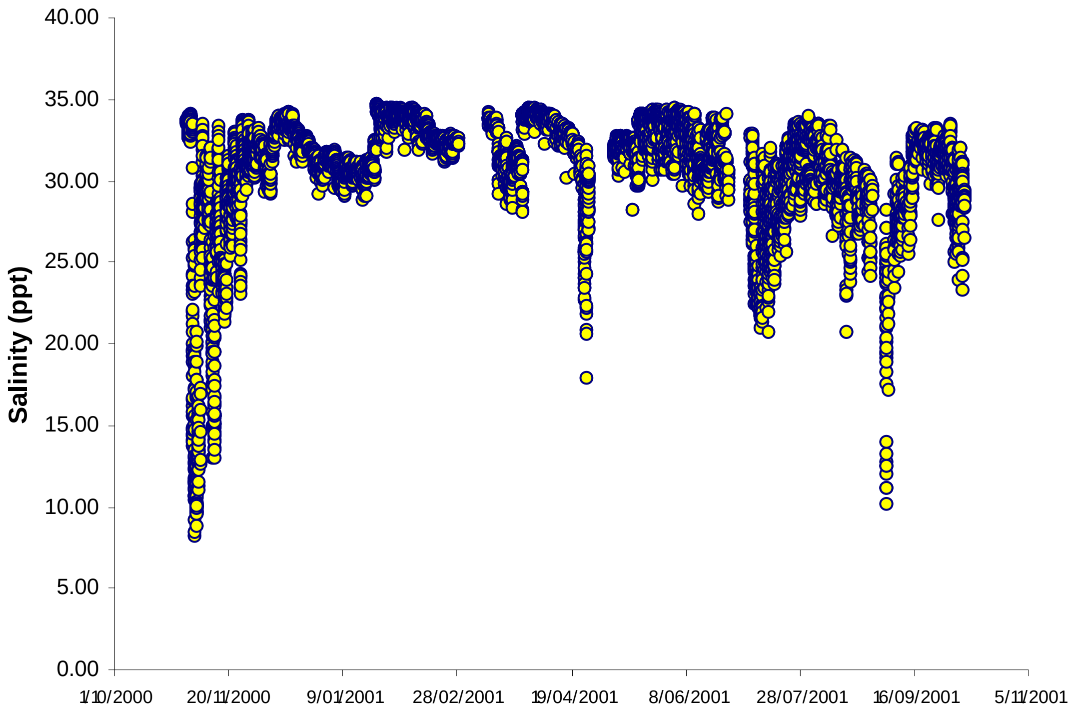

Figure 6. Salinity throughout 2000/1 as recorded by a continuous data logger on an oyster lease near the mouth of the George River

The movement of freshwater in Georges Bay is complex, depending on wind direction & speed, tidal stage and freshwater inflow volume. For instance, in normal flow conditions, Brown & Turnbull (2003) suggests that the salinity of Moulting Bay is most likely to be effected the most when the wind direction is from the south/south east and there is a flood tide. However, when there is no wind, the freshwater is more likely to form a surface layer which flows down the channel and out into the open ocean.

Consequently, salinity is rarely uniform across the whole of the Bay. The salinity data collected by TSQAP in 2004 at eight sites is shown in Figure 7. Salinity fluctuates by almost 10 ppt at some sampling sites, with the lowest salinities occurring at sites within Moulting Bay (sites 1, 3 & 4). Similarly, the results from Crawford & Mitchell (1999) imply a highly variable salinity pattern over the Bay, with the lowest salinities generally ocurring near the George River outflow.

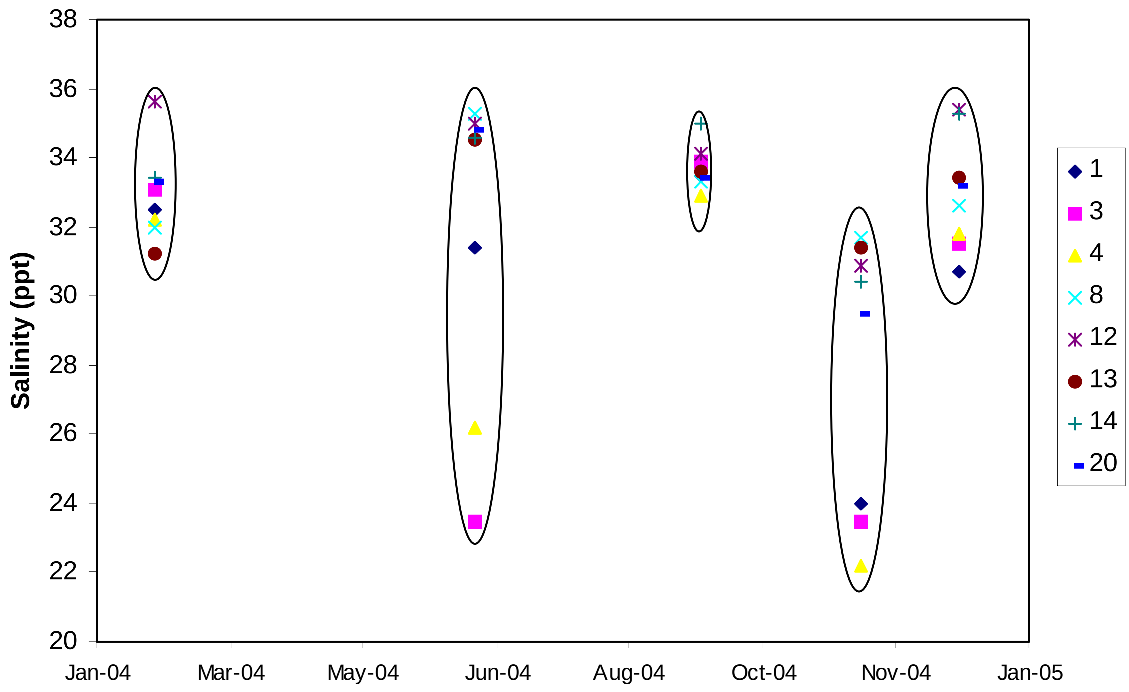

Figure 7. TSQAP salinity monitoring at eight sites across Georges Bay (see Appendix 2) Circles highlight salinity ranges across Georges Bay for each sampling event

The flow of the George River is measured by a continuous monitoring station run by DPIWE at Priory. This station came into action in May 2004 and can be used to determine the volume of freshwater entering the Bay from this point onwards.

Salinity is presently being monitored as part of the ongoing TSQAP program in Georges Bay.

pH

pH is a measure of the acid balance of water and strongly influences many chemical and biological processes. There have been very few surveys that have addressed water pH in Georges Bay.

Monitoring at the sewage outfall pipe by Break O'Day Council suggests the effluent discharging into the Bay is alkaline, with the average value around 9.1. Whilst this is above the DPIWE emission guidelines, monitoring by Break O'Day Council shows that this value can drop to within an acceptable range within 75 m of the outfall pipe.

K. Saunders (UTas, unpub. data) measured pH in water 1 m deep at six sites around Georges Bay on the 1st August 2004 and 8th February 2005. All readings ranged from neutral to slightly alkaline, with summer pH more alkaline than winter pH (Figure 8). All values recorded were within the DPIWE draft water quality targets for Georges Bay which suggest a pH range of 7.0 to 8.5, except the result from Lord's Point in winter, which had fallen below the lower limit of 7.0.

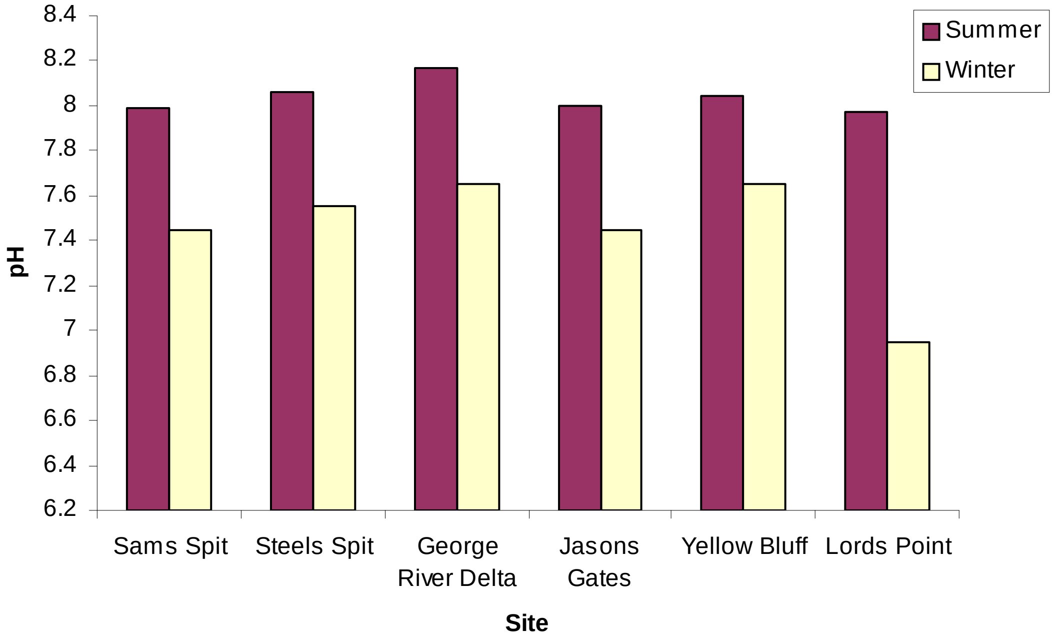

Figure 8. pH of Georges Bay

Given the history of the Georges Bay catchment areas, the majority of reports raise concerns about elevated acidity, and not alkalinity. There has been some concern about acid drainage from sulphate soils, particularly following heavy rainfall. Percival (2004) suggests that acid-sulphate soils do exist around St Helens, although their extent and subsequent effect on the water pH of Georges Bay is unknown.

Waterwatch has reported acid drainage and low pH values around the old Anchor Mine site near Lottah. However, as most mining activity in the Upper George River catchment was conducted on granitic, not sulphidic rock, large scale acid drainage may not be a major issue (Percival, 2004). Monitoring of the catchment by DPIWE has also recorded low pH values intermittently (~ 4.5), although the majority of values tend to be within a normal range for freshwater (see Appendix 3).

Data collected from the continuous monitoring station at Priory has recorded relatively normal pH values. However, the continuous monitoring station has not been operational during a heavy flood event. Hence, there is no information to indicate what pH values may do directly following high rainfall, or what the subsequent effects on Georges Bay may be. A more consistent monitoring regime for pH in Georges Bay is necessary.

Biological Oxygen Demand

Biological oxygen demand (BOD), which is a measure of oxygen demand by microbial breakdown of organic matter, has been regularly monitored in larger Tasmanian estuaries, such as the Derwent River, and is a useful measure of organic waste being discharged to the water column from storm water and sewage outlet pipes. However, the relevance of BOD in a receiving environment is debatable as the ‘normal’ levels in receiving waters are very low (< 4 mg/l), and this measure is generally too coarse to be useful.

One of the major sources of organic waste in Georges Bay is the sewage treatment plant outlet, which is monitored for BOD regularly. Break O'Day Council take monthly readings at the outlet site, the results of which are shown in Figure 9. Results are quite variable throughout the time period shown, with the average being 44.75 mg/L and maximum and minimum values 23.5 and 89.1 respectively. This is significantly higher than the recommended DPIWE maximum emmision guideline value, which suggests 20 mg/L in normal conditions (SKM, 2005) or 40 mg/L when there is an algal bloom.

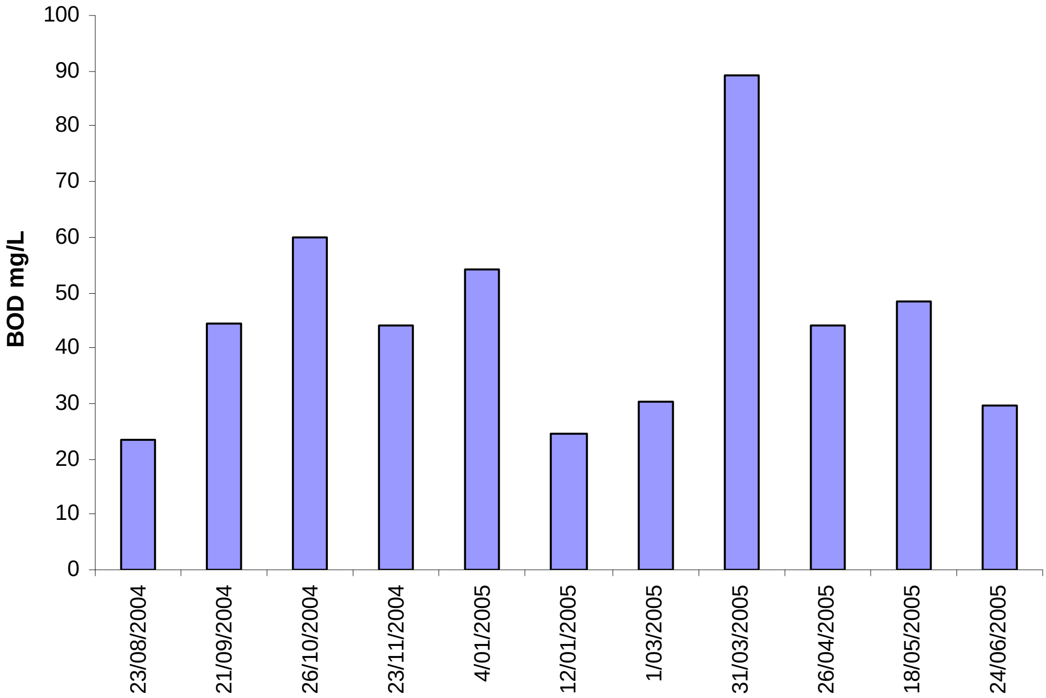

Figure 9. BOD(mg/L) at the St Helens sewage outlet pipe

Monitoring by Break O'Day Council suggests that the levels of BOD in the water column drop to <5 mg/L within 75 m of the outfall pipe (SKM, 2005). Moreover, the proposed wastewater treatment plant upgrade should lower this emission value to within DPIWE emission guidelines.

BOD is subject to ongoing monitoring by Break O'Day council.

Dissolved Oxygen

Dissolved oxygen measures the levels of oxygen in the water column. It is a basic requirement of all aquatic species, with some species more sensitive to lower levels than others. Low dissolved oxygen values are often linked to contamination by biodegradable organic substances, leading to high biological oxygen demand (Aquenal, 2004). Despite this being a very important variable in terms of estuarine health, there have been very few measurements of dissolved oxygen in Georges Bay.

Turbidity

Turbidity is a measure of water clarity and light penetration. Many factors influence turbidity, including levels of phytoplankton, dissolved substances and suspended matter within the water column.

There have been very few studies addressing turbidity in Georges Bay. Anecdotal evidence suggests that turbidity levels are quite high. For instance, video footage taken by Crawford et al. (2001) was too poor to survey features of the seabed due to a high concentrations of suspended solids. Similar conditions were reported by Aquenal Pty Ltd (1999) when doing baseline video surveys on proposed marine farm development sites.

However, when Crawford et al. (2001) measured turbidity in Moulting Bay, values ranged from 1-2 NTU. These values are classified as "low" using the draft indicator levels set by Murphy et al. (2003). Turbidity was also measured by K. Saunders (UTas, unpub. data) as part of a PhD project with the University of Tasmania. Values ranged from 5 to 8, which is still only a "medium" classification by Murphy et al. (2003).

These two studies are the only occasions in which turbidity has been measured directly in Georges Bay and results are contradictory to observatory and anecdotal evidence. As high turbidity was tagged as a potential concern for the Bay by Percival (2004), consistent monitoring of this parameter is suggested.

Nutrients

Nutrients are an essential component of all ecosystems as they are the building blocks of all living organisms. Key nutrients include nitrogen (N), phosphorous (P), carbon (C) and silica (Si). However, too little or too much of these nutrients can have major detrimental effects on living systems. In the marine environment nitrogen is commonly the limiting nutrient. Insufficient nitrogen will decrease the productivity of the estuarine and marine environment. Conversely, greatly increased concentrations of nitrogen, which can occur as a result of land-based activities, such as fertilizer run-off from agricultural activities, effluent from dairy farms, sewage etc, can result in markedly increased productivity. In extreme cases this leads to eutrophication of estuaries whereby major algal blooms and /or production of macroalgae occurs, and the breakdown of this excess material by bacteria utilises all the available oxygen. This impacts on animals living in this system, leading to fish kills etc. Because estuaries are commonly nitrogen limited, they are generally most sensitive and reactive to increased levels of nitrogen into the system. Conversely, freshwater ecosystems, are commonly phosphorous, rather than nitrogen, limited.

There are various forms of nitrogen and phosphorous in the water column that can be in dissolved organic, dissolved inorganic or particulate form. Dissolved organic nitrogen (DON), such as urea (active) and humic substances (non-active) and particulate nitrogen (PN) generally make up the largest pools of nitrogen in the water column. The dissolved inorganic (DIN) forms of nitrogen – ammonium NH_4, nitate NO_3 and nitrite NO_2 and dissolved inorganic phosphorous - phosphate PO_4, although generally in lower concentrations, are most important to estuarine health as they are the biologically available forms of these nutrients, i.e. are most readily utilised by plants and animals.

Nutrients have not been routinely sampled in Georges Bay. Data are available from two studies: Crawford et al (1999) sampled nitrate + nitrite (commonly referred to as NO_X), phosphate (PO_4) and towards the end of their study silicate (SiO_4) at 4 sites throughout the estuary and one marine site over a 11 month period in 1993/94 (Fig 3). Sinclair Knight Mertz as part of a consultancy to the Break O'Day Council on upgrading the St Helens waste water treatment system sampled 3 sites in the upper estuary and 1 site at the Compass Bridge (Fig 3) periodically from November 2004 to June 2005. Two sites were similar to those sampled by Crawford et al (1999).

Results from Crawford et al (1999) showed variation in NOx values over the sampling period (Fig. 10). Highest concentrations were recorded over winter, reaching a peak of over 60 μgl^{-1} in July; highest concentration of chlorophyll a was also recorded at this time in the upper estuary. NOx values were consistently highest at the marine site, averaging 22.9 μgl^{-1} over the 11 month sampling period, indicating oceanic influxes of nitrogen. Lowest values were recorded at Mast and Lords Point sites over the sampling period, averaging 6.9 and 5.85 μgl^{-1}, respectively. However, much higher values of NOx have been recorded in the plume of freshwater entering Georges Bay from the Georges River after heavy rainfall (Crawford et al 1999).

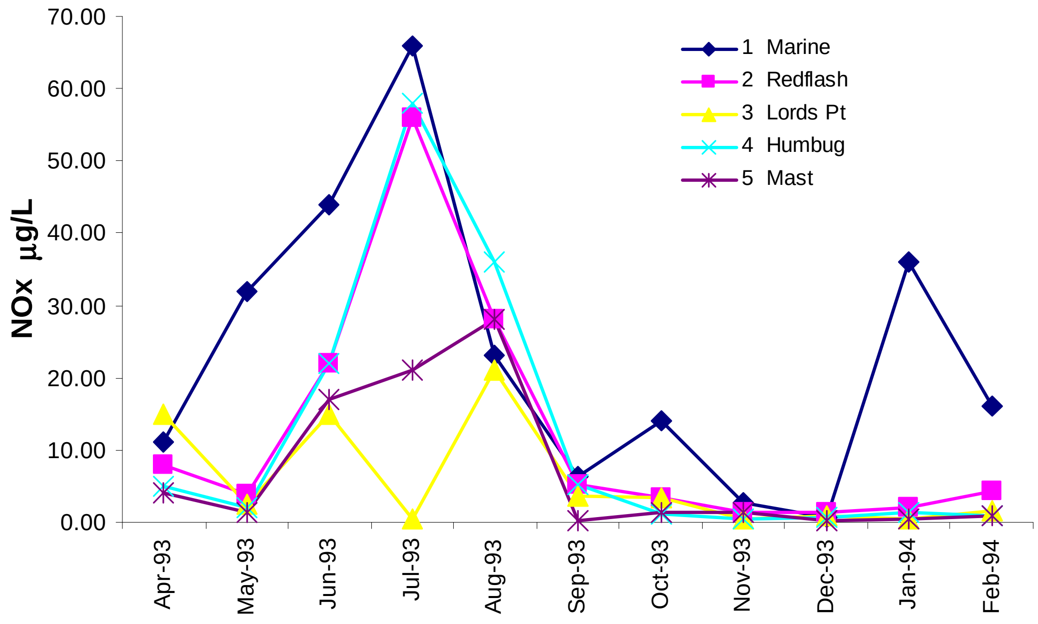

Figure 10. NO_X in Georges Bay from April 1993 to February 1994 (from Crawford et al., 1999).

No distinct seasonal trends in phosphate concentrations were observed (Fig 11) and they generally ranged between 5 and 15 μgl^{-1} , with the Marine station having the highest levels in most months. Silicate concentrations were only measured in the last four months of sampling. They averaged 192 μgl^{-1} and were clearly lowest at the marine site.

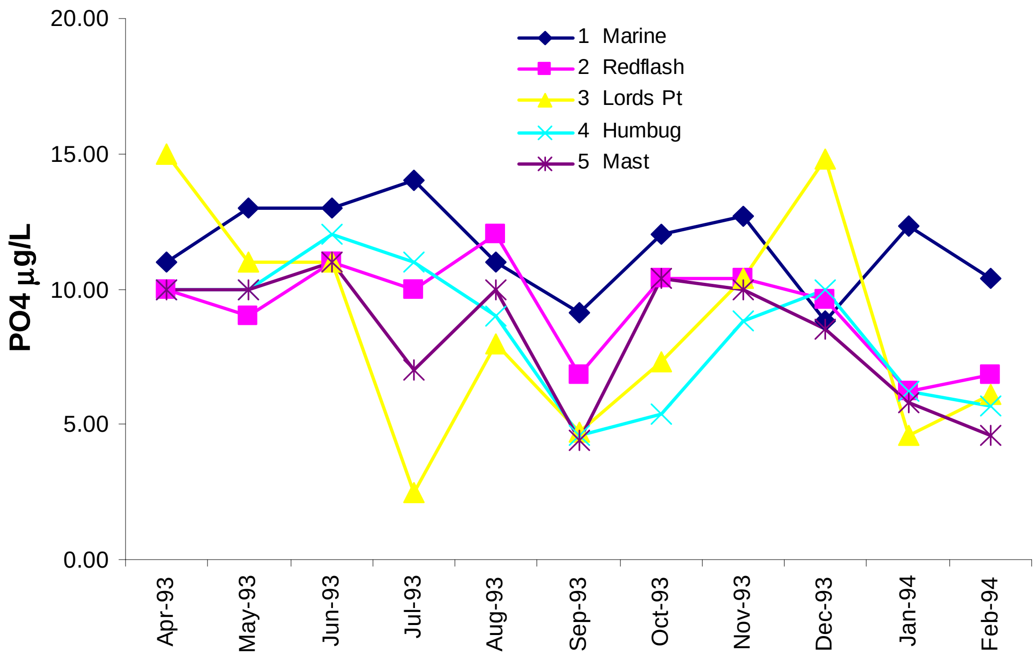

Figure 11. PO_4 in Georges Bay from April 1993 to February 1994 (from Crawford et al., 1999)

The concentration of NOx in 2004-05 at the two sites, Mast and Lords Point, which were also sampled in 1993-94, showed little change except for a relatively high value at Lords Point in April 2005 (Fig 12). The Compass site also had low concentrations of NOx, whereas the Bridge site had much higher concentrations on most sampling occasions. For the three sampling sites in the estuary, two thirds of the measurements were at or below the minimum detection limit of 10 μgl^{-1}.

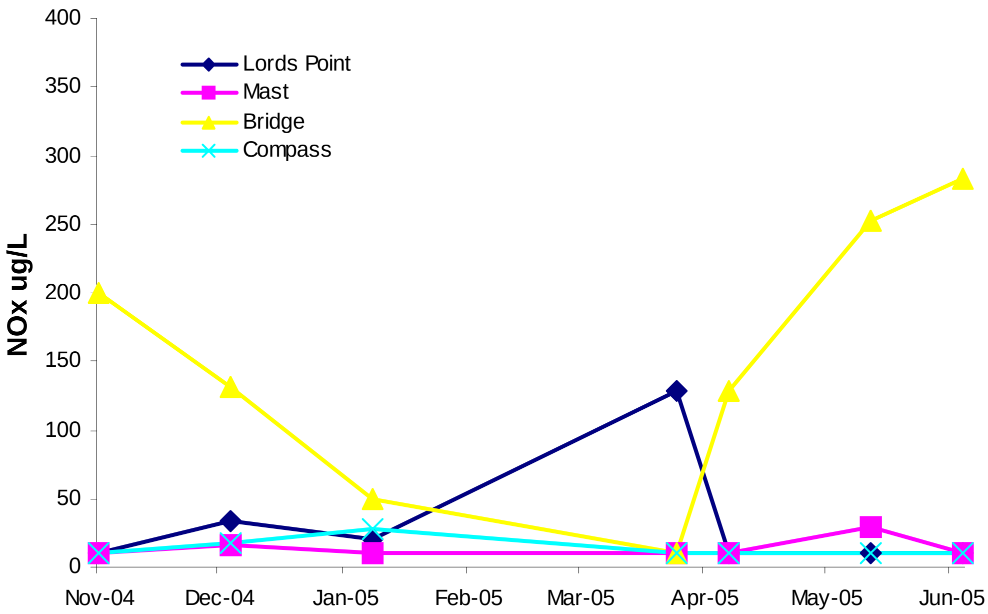

Figure 12. NO_X in Georges Bay November 2004 to June 2005 (from SKM)

The ammonia concentration at the Mast sampling site was extremely high in November 2004 (Fig 13). It was also slightly elevated at the Bridge at Compass sites at this time. Otherwise, ammonium concentrations were generally relatively low, except for an increase at Lords Point in April 2005. 79% of all ammonia measurements were at or below the minimum detection limit of the analysing equipment.

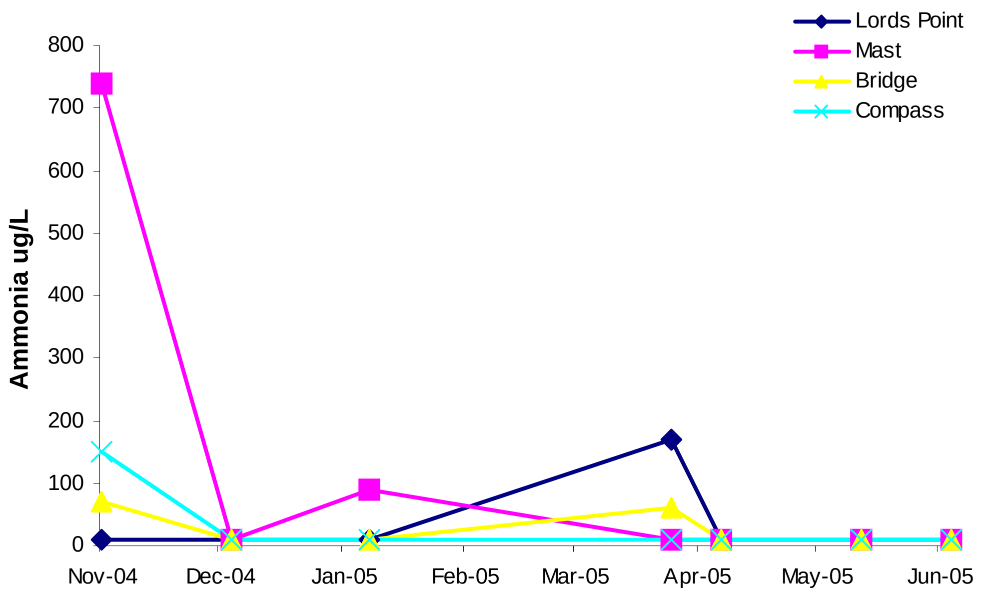

Figure 13. Ammonia in Georges Bay November 2004 to June 2005 (from SKM)

Peak values of total N tended to show similar patterns to the peak NOx and ammonia concentrations, with maximum values at the Mast site in November 2004, at the lords Point site in April 2005 and at the Bridge site in November 04 and June 05 (Fig 14). The Compass site off the sewage outfall generally had low nitrogen values and did not show any major peaks during the sampling period.

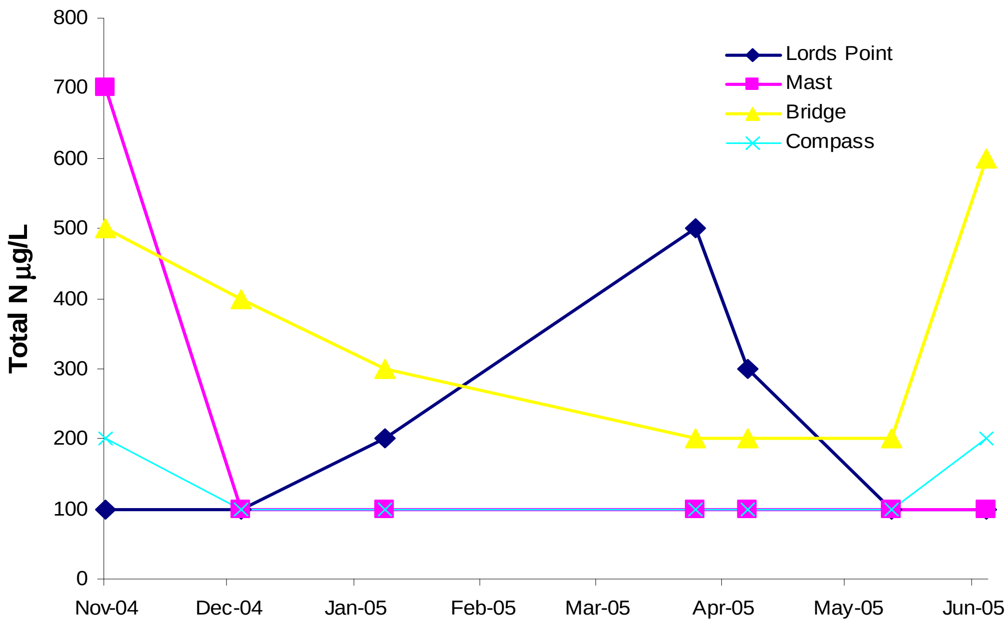

Figure 14. Total Nitrogen in Georges Bay November 2004 to June 2005 (from SKM)

Total P was relatively low for most of the sampling period except for May and June 2005 when peak values were recorded at the three sites in the estuary (Fig 15).

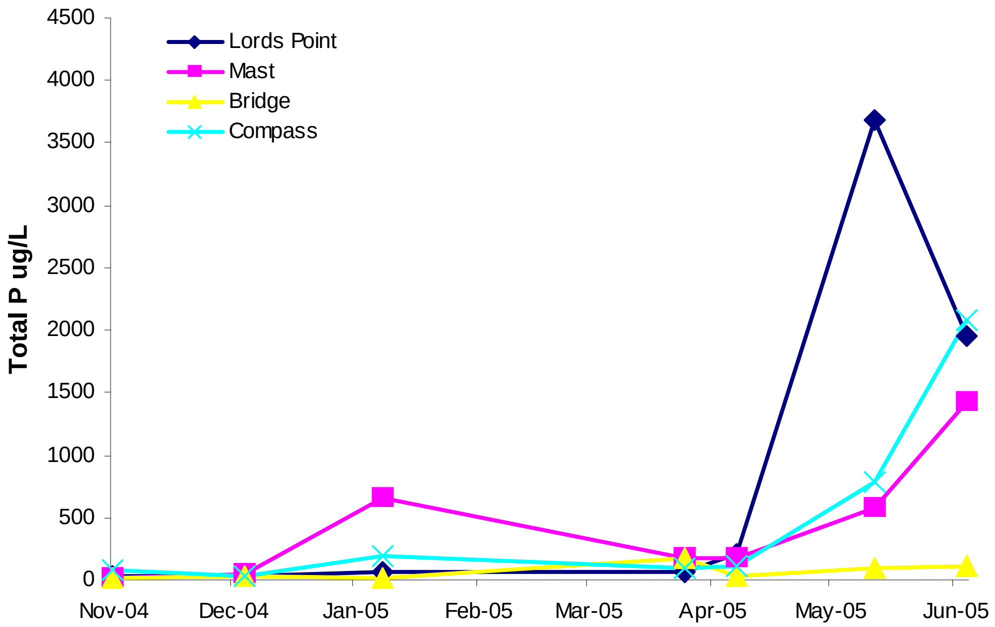

Figure 15. Total Phosphorus in Georges Bay November 2004 to June 2005 (from SKM)

Sediment Characteristics

Sediment characteristics are often a reflection of the comparative health of the water column. For instance, the study by Crawford et al. (2001) around the oyster leases in Moulting Bay surveyed particle size of the sediments, finding that they were extremely fine, being comprised almost entirely of silts and clays (<63 µm). This result is supported by the baseline environmental assessments conducted by Aquenal Pty Ltd in 1999 for DPIWE (2004) in Moulting Bay. The very fine particle size of sediments within the Bay make them highly susceptible to resuspension in the water column. This is likely to make a significant contribution to the high turbidity anecdotally reported in the Bay.

When surveyed by Aquenal Pty Ltd for DPIWE, all sites in Moulting Bay also tended to have very organic sediments and redox values that indicated low oxygen availability at the water/mud interface. However, the results for Moulting Bay were not necessarily consistent across the entire Georges Bay region. For example, sediment at Hodgmans Spit was sandy in nature and had a particle size that was much more evenly distributed across several different size categories. This indicates variable water movement across this area of the Bay (DPIWE, 2004).

Similarly, sampling in the Pelican Point region revealed fine and sandy sediments, predominantly of marine origin. The particle size distribution was typical for fine sandy sediments, being around 125 µm. Organic content was relatively low, and nature of the sediment implied constant regimes of moderate water movement across survey area (DPIWE, 2004). Of interest, all cores collected by Aquenal Pty Ltd showed some black sediment within the chronology, indicating anoxic (low oxygen) conditions have been prevalent in sites across Georges Bay in the past.

Hence, sediment characteristics have a tendency to be quite variable across a region, and are highly dependent upon localised water regimes. Water movement has a strong influence on sediment deposition and oxygenation of the sediments. For example, Moulting Bay sites with low water movement tended to have finer sediments than sites within the strait, where there is strong tidal flow. Thus, surveys of the sediment can provide clues to the past and present flow conditions.

Sediments in Georges Bay were sampled at 33 sites as part of habitat mapping of Georges Bay (Mount et al, in prep.). The results shown in Fig 16 also indicate high levels of silts and clays, especially in the deeper central basin, the inner harbour and inside Moulting Bay. Other shallower areas generally had a high proportion of sand compared with silt.

The habitat map developed for Georges Bay by Mount et al (in prep.) clearly shows the large areas of seagrass beds in the estuary (Fig. 17). The distribution of unvegetated habitat into mainly silts in the upper estuary and predominantly sand in the lower estuary is also obvious in Fig. 17.

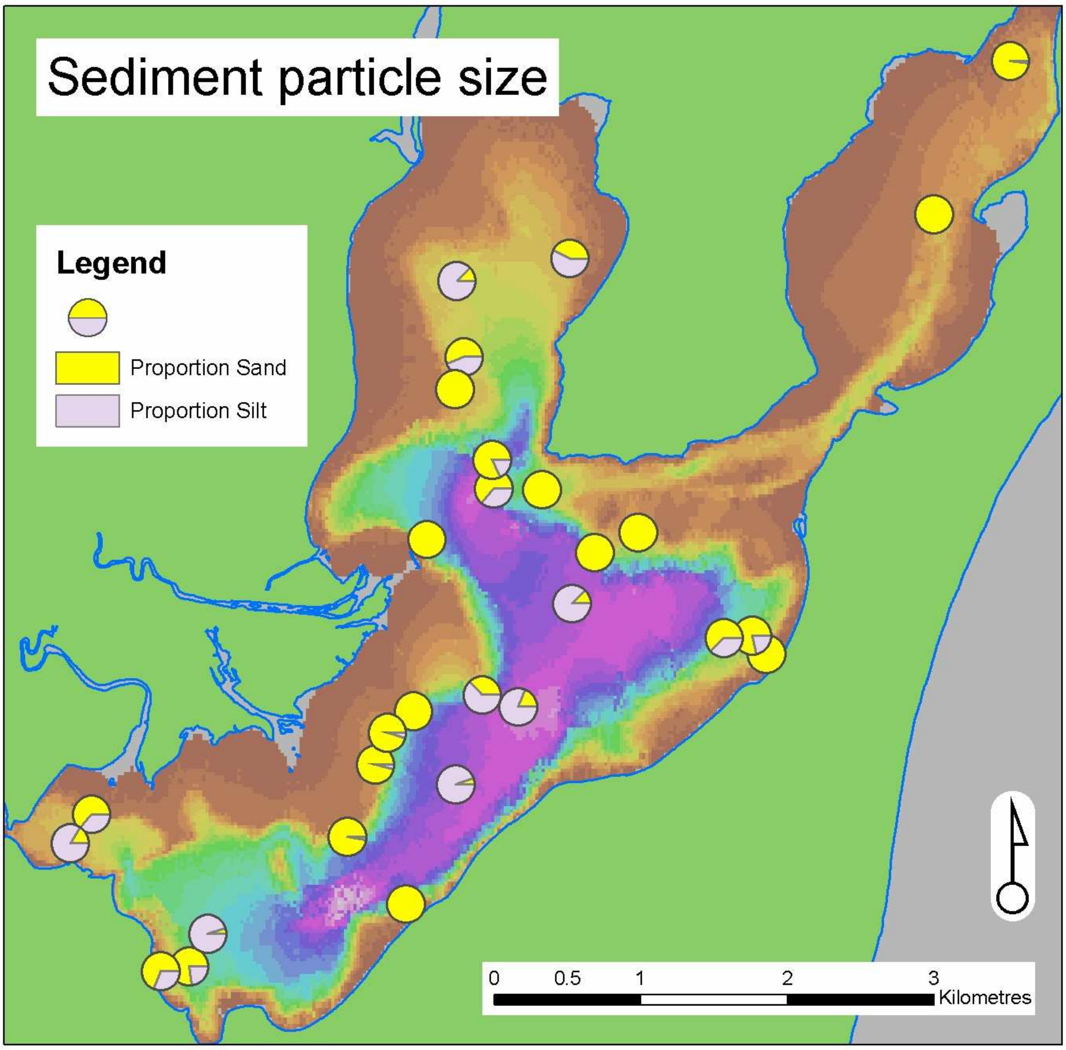

Figure 16. Proportion of sand to silt in sediment samples in Georges Bay. From Mount et al (in prep.)

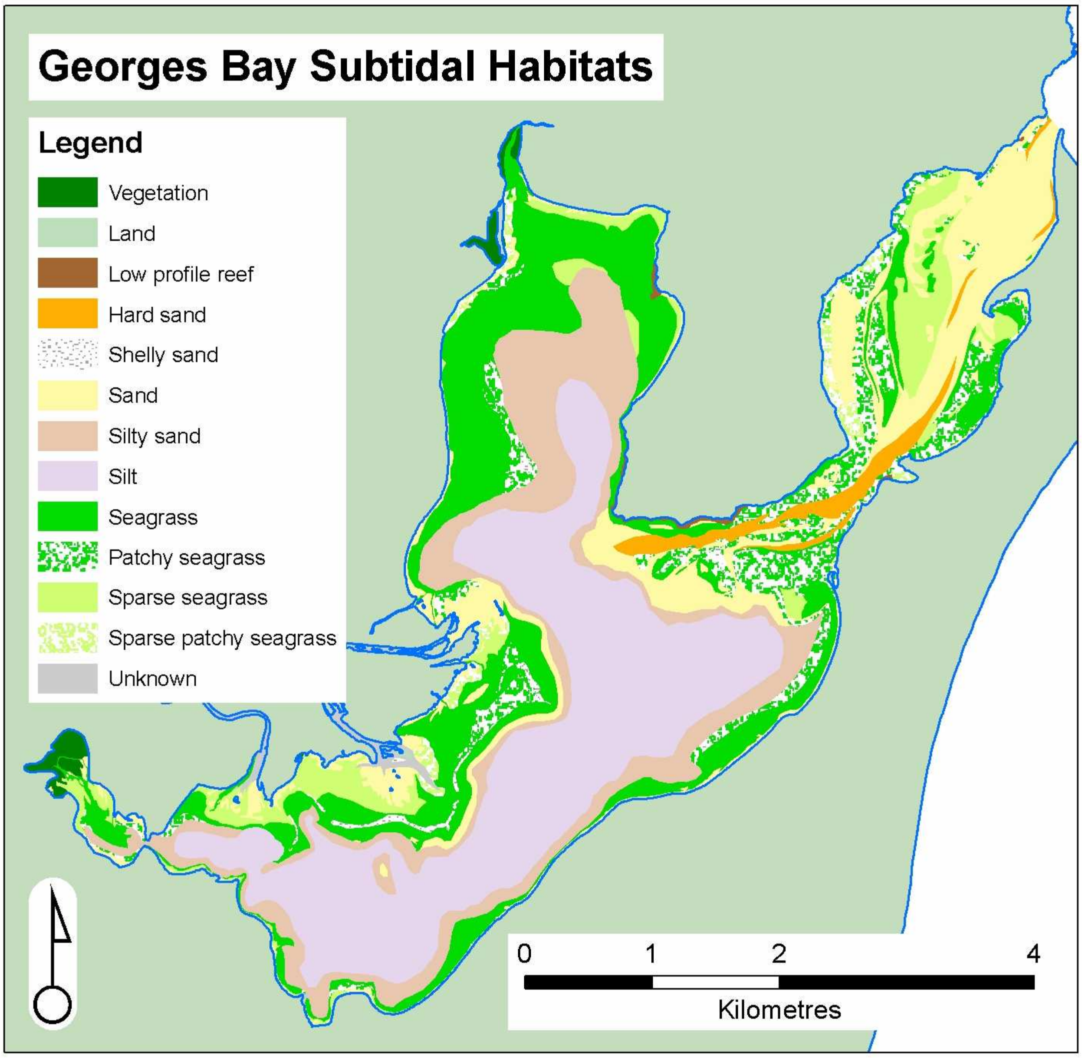

Figure 17. Habitat map for Georges Bay (from Mount et al, in prep.)

Benthic Fauna in the Sediment

Benthic infauna (animals living in the substrate) provides a valuable linkage between chemical properties of the estuary and health of an ecosystem. Composition of infaunal communities has been applied in previous studies (see McCleod et al. (2002), McCleod et al. (2004)) as an indicator of ecosystem health.

The benthic infauna of Georges Bay was surveyed by Crawford et al. (2001) as part of the TAFI survey examining impacts of shellfish on the benthic environment. Polychaete worms were found to be the most common faunal group, comprising of 39% of species recorded, with Nemertean worms also important (19%). Overall St Helens recorded significantly lower number of species and individuals per site when compared to Eaglehawk Bay and Port Esperance. Similarly, surveys conducted by Edgar et al. (1999) also reported a low species diversity, with 46 species reported along three transect lines.

Aquenal Pty Ltd has also conducted several macrobenthic infaunal surveys in Georges Bay, both in Moulting Bay and the proposed sewage outfall line. Results from their

Moulting Bay (1999) survey are similar to that of Crawford et al. (2003) and Edgar et al. (1999) and indicate that the benthic infauna is depauperate in terms of species richness and abundance of individuals. These results, however, were comparably similar to other sheltered estuaries in Tasmania where sediments are very silty and contain high levels of organic material (Aquenal Pty Ltd, 2004).

The sampling program around the proposed sewage outfall site revealed a relatively diverse macrofaunal assemblage (Aquenal Pty Ltd, 2004). Similar to the study by Crawford et al. (2003), polychaete worms dominated the sites, comprising 41% of species. However, crustacean fauna, particularly amphipods were the best represented taxon, followed by molluscs. The most common species were the capitellid polychaete, *Capitella* sp. and the spionid polychaete *Malacoceros tripartitus*. Previous studies in Tasmania have recorded these species in areas with increased organic loading (e.g. McCleod et al., 2002). These species were absent from samples collected for studies based in Moulting Bay. Of note, sites located a considerable distance from the present and proposed outfall locations were characterised by relatively high diversity, but low numbers of individuals, being typical of unimpacted sites (Aquenal Pty Ltd, 2004). By applying this “fingerprint” to other regions of the Bay, the benthic infaunal communities could be useful in the monitoring of estuarine health in the future.

Chlorophyll a

Chlorophyll a is a measure of microalgal (phytoplankton) biomass. It is often included in monitoring programs as an indicator of the density of phytoplankton because excess nutrients commonly result in increased production of phytoplankton, which can result in major algal blooms that may have significant deleterious effect on the health of an estuary.

However, only one data set for chlorophyll a could be found for Georges Bay. Crawford and Mitchell (1999) measured chl a monthly at 5 sites from April 1993 to February 1994 (Fig 18). Chl a concentrations were generally in the range of 1-4 μgl^{-1}, except for a value of 13.5 μgl^{-1} in the upper middle estuary in July and two sites around 7 μgl^{-1} in February 1994. The mean value for chlorophyll a at each site over the 11 month sampling period was from 2.2 at the marine site to 3.3 μgl^{-1} at the site in the middle upper estuary. Intensive sampling in a short period of time in Moulting Bay and around Humbug Point and near the entrance of the Georges River on several occasions produced varied results. High values of chl a (bloom conditions, maximum value 35.8 μgl^{-1}) were recorded in June 1993 and February 1995 (after rainfall). The chlorophyll a concentrations on some occasions were noticeably higher in Moulting Bay than in Georges Bay proper and were higher at high than low tide.

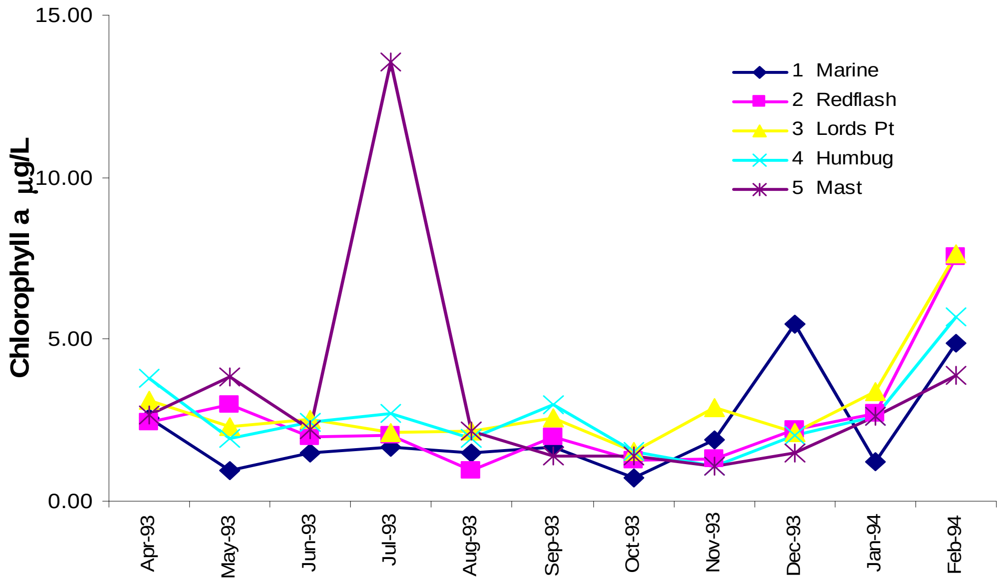

Figure 18. Chlorophyll a in Georges Bay April 1993 to February 1994 (from Crawford et al., 1999)

Algal Blooms

TSQAP have been monitoring the algal species of Moulting Bay in 2001 and on a regular basis since January 2003. This program is essentially concerned with toxic algae, although some full algal counts have also been done. Full algal counts indicate that the phytoplankton community is dominated by relatively benign diatom taxa such as *Skeletonema*, *Leptocylindrus* and *Chaetoceros*, sometimes in numbers in excess of 100,000 cells/L.

Toxic and nuisance species are said to be in "bloom" conditions at much lower concentrations than benign taxa (Hallegraeff, 2002), as smaller concentrations of these cells can have a much greater impact. The toxic dinoflagellate *Gymnodinium catenatum* has been recorded in Georges Bay. This dinoflagellate species was introduced into Tasmanian waters in 1973, and is a producer of paralytic shellfish poisons that can cause neurological and gastrointestinal problems in humans (Hallegraeff, 2002). Georges Bay is regularly monitored for this species, the results of which are shown in Figure 19.

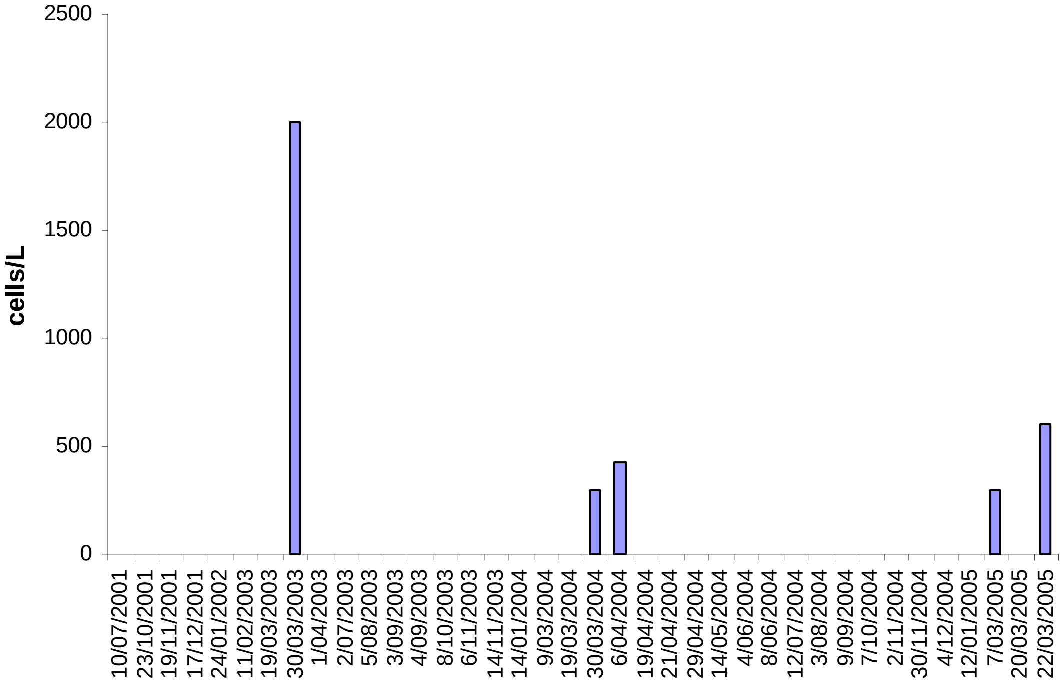

Figure 19. Concentrations of *Gymnodinium catenatum* in Georges Bay 2001-2005

Gymnodinium catenatum concentrations begin to be of concern when they reach around 2000 cells/L (A. Turnbull, TSQAP, pers. comm). Once detected by TSQAP, they increase sampling to weeklyevents until cells are no longer present in samples. *Gymnodinium catenatum* has been detected by TSQAP in numbers approaching that of concern, although blooms appear transient and numbers do not reach high enough levels to be of real biotoxin risk. There is currently no history of shellfish farm closures due to toxic dinoflagellate blooms in Georges Bay, although paralytic shellfish toxins have been detected, albiet at low levels.

The algal community of Georges Bay, as sampled by TSQAP, is rich and diverse when compared anywhere else in Tasmania. There are generally high numbers of algae, with a high diversity that is maintained for a prolonged period of time. This is particularly the case when compared to other east coast estuaries, such as Little Swanport and Great Swanport (A. Turnbull, 2005, pers comm). The monitoring of algal species in Georges Bay by TSQAP is ongoing.

Following the major flood event of February 2004, DPIWE also sampled the algal communities of Georges Bay. One week following the flood, once off sampling occurred around oyster leases and in the channel. There were very few algal cells recorded, suggesting that the massive flood event had effectively flushed the Bay, with the communities yet to re-establish (J. Marshall, DPIWE, pers comm).

Seagrass

Sheltered estuaries and bays with unconsolidated substrates provide a suitable environment for seagrasses to grow. Seagrass is an underwater flowering plant that forms large beds in intertidal and subtidal areas and are a key component of the primary production systems within an estuary. They convert sunlight and nutrients into food for the organisms that live higher up the food chain. They also help to stabilise the sediments and are a home and a nursery to a large variety of fish and invertebrate species.

There are two species of seagrass known for Georges Bay; *Heterozostera tasmanica* and *Zostera muelleri*, which are virtually identical without microscopic inspection. However, a key difference between the species is that generally only *Zostera muelleri* is found in the intertidal zone, though it can grow subtidally as well. This means that while it is difficult to efficiently differentiate between the species below the low water mark, most of the seagrass exposed at low tide is likely to be *Zostera muelleri*. Seagrasses only grow to depths where they can obtain sufficient sunlight for photosynthesis. As the amount of light reaching the sea floor is largely controlled by the water clarity, the depth to which seagrass grow is an approximate indicator of the average water clarity conditions in the immediate area. The seagrass grows to a maximum depth of about 6.25 m along the southern shores of the bay and at McDonalds Point. The shallowest maximum depths are found in the inner harbour (about 2.7 m) area and Moulting Bay (about 3.4 m).

The seagrass in Georges Bay is very abundant at present (688 Ha) and has been consistently so for the past 3 to 5 years. When compared to previous mapping done for circa 1950 and circa 1990 (Rees, 1993), there is substantially more seagrass present in the bay, notably in the very shallow nearshore areas. The previous mapping effort is regarded as unreliable in the deeper water as it did not have access to underwater video technology. The level of epiphyte abundance was also found to be generally low
.
It is difficult to assert a cause for the large fluctuations in the extent of seagrass in the bay as the seagrass responds to a large number of variables including exposure, depth, water clarity, temperature, UV, salinity, grazing pressure (swans and invertebrates), storms, nutrient levels and sedimentation rates. It is thus difficult to distinguish between human induced and natural variations. Clearly, the conditions for seagrass growth are currently optimal. There are negligible signs of direct disturbance in the bay, such as anchor chain scouring damage.

Fish Communities

There have been few quantitative surveys on the fish communities in Georges Bay. Jordan et al. (1998) surveyed the demersal and larger mobile fish fauna in various habitats around Georges Bay. They found that distinct fish communities existed at different sites within the Bay, largely dependent upon habitat. Sites with dense seagrass tended to have a distinct community, with the spotted pipefish *Stigmatopora argus*, and the wide bodied pipefish *S. nigra* often dominant. Communities were generally stable, with high numbers of smaller fish of all life history stages. Overall the seagrass of Georges Bay contained a large number of unique species compared to other eastern Tasmanian estuaries.

Many fish species make use of the unvegetated habitats of Georges Bay. Typical species found in these areas include leatherjackets, hardyheads, flounders, eastern Australian salmon and mullets (Jordan et al. 1998). Shallow unvegetated areas tended to be important nursery grounds for demersal families such as gobies (Gobiidae), flounder (Pleuronectidae) and flathead (Platycephlidae), with communities more transient in nature compared to seagrass.

Oyster Mortalities

Georges Bay produces approximately 21% of Tasmania's Pacific oyster production. All the oysters in Georges Bay are being ongrown to market size and most have come from the Smithton area as small spat.

Since 1997 Pacific oyster farmers of Georges Bay have experienced unexplainable health problems, including mortality events, shell deformities and slow growth rates (Percival, 2004). The overwhelming majority of unexplained mortality events are reported to occur after rainfall and subsequent flooding or following handling procedures in spring and summer. The severity of the mortality event varies according to the degree of handling and/or the magnitude of the rainfall event (Percival, 2004). Since 1997, it is estimated that the oyster farmers of Georges Bay lose between $20,000-50,000 of stock per annum (B. Leahy, pers comm).

Health issues in commercial oyster leases tend to occur within 2 to 6 weeks following a flood event. Oyster meat samples are sent off to the Fish Health Unit, where they undergo pathological testing with the aim of establishing cause of death. At this stage, testing by the Fish Health Unit has given no definitive reason for oyster ill-health (B. Leahy, pers comm).

The largest oyster mortality event occurred in February of 2004 following a heavy rainfall event that resulted in the highest recorded flooding of the George River. Nine days after heavy rainfall commenced, oyster farmers reported significant oyster mortality. Mortality was localised to intertidal leases in Georges Bay and Moulting Bay, with no significant mortalities occurring on subtidal leases, or intertidal leases near the Georges Bay Entrance. The total loss of stock amounted to nearly $2 million dollars.

Histological results from the major flood of February 2004 indicated that environmental stressors were a major contributor to the mortality event (Percival, 2004). Numerous observations made by oyster farmers also suggested that a narrow band of water at the surface was associated with the bulk of oyster deaths on intertidal leases (B. Leahy, pers comm). It is possible that a pollutant located in the surface water was responsible for the mortality, or at least acted as a contributing factor. Of interest, since oyster ill-health problems commenced around 1997, mortalities are only very rarely reported from leases on Zone 6A, near the St Helens Barway, which have been in operation since 1998.

The Percival (2004) report on oyster health in Georges Bay provides the largest collation and analysis of data associated with oyster mortality events to date. This report suggets that there is no apparent single cause of oyster health problems in Georges Bay. Rather, a complex web of factors appear to be rendering the oysters susceptible to additional stressors, such as a flood event.

The problem of oyster ill-health in Georges Bay is ongoing. Since February 2004 there has been another 6-8 reports of oyster mortality in Georges Bay, almost always following a flood (B. Leahy, pers comm). The mortalities have been observed to be not related to the size of oysters. Studies to investigate the cause of mortality are currently being discussed and funding is being sought.

Toxicants

There has been considerable concern over potential contamination of Georges Bay by a range of substances including herbicides/pesticides and heavy metals. Consequently, a range of testing for these substances has been undertaken by many different organisations. DPIWE has recently purchased new equipment which will be able to measure many toxicants to much lower detection limits than the current instrument which measures to around 0.05 µg/l. Collectively both instruments should produce data that will satisfy the required detection levels for pesticides for drinking water and the majority (if not all) of default low reliability trigger values for pesticides for the protection of aquatic ecosystems, as detailed in the national guidelines. Of note is that the trigger values for pesticides on most occasions have been determined by dividing the lowest actual level which is chronically or acutely toxic to crustaceans, insects or molluscs by an arithmetric factor of 100-1000, depending on the paucity of toxicological data.

As part of a statewide initiative, DPIWE has commenced regular testing for pesticides and herbicides on the George River. The George River has been sampled five times since testing commenced in January 2005, including a flood event in February. At this point there has been no record of any chemical above detectable limits.

Following significant publicity in 2004 that proposed that oysters in Georges Bay were killed by chemicals used in aerial spraying, TSQAP also conducted a range of tests in oyster meat. No organo-compounds used in pesticides were detected in any sample, and levels of heavy metals were insignificant (Figure 20). The oyster industry, however, is concerned about the potential effect of combinations of chemicals on oysters.

In response to public concerns regarding contaminated water supply, throughout 2004 the Break O'Day council also commenced monthly water testing for pesticides and herbicides on the George River. Similarly to the testing conducted by DPIWE, there were no chemicals recorded above detectable limits over the period of the study.

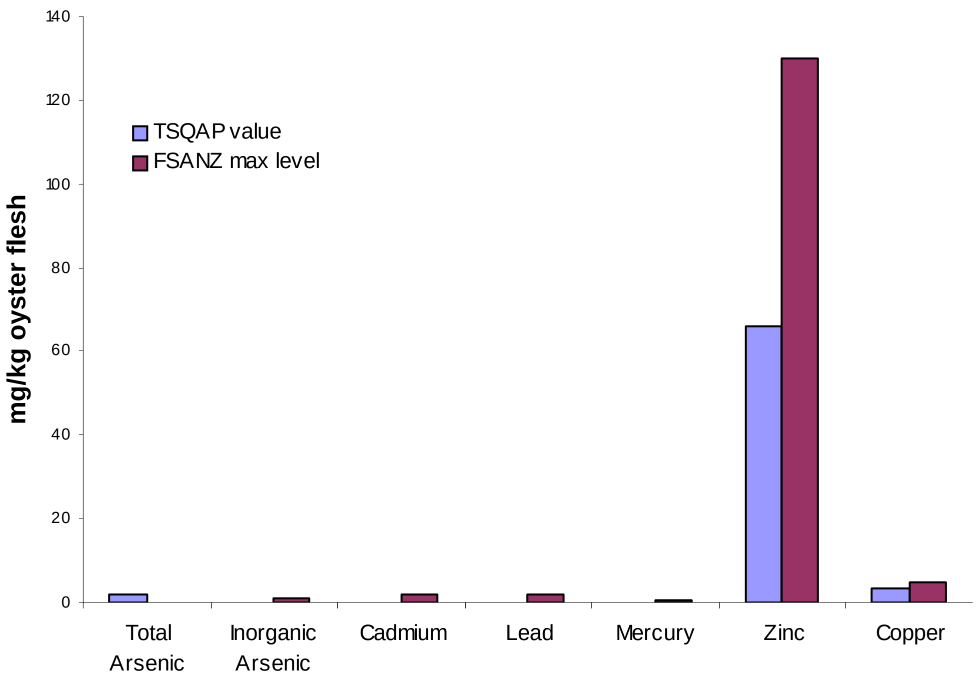

Figure 20. Levels of heavy metals in oyster meats from Moulting Bay, 2004

Tributyl tin compounds (TBTs) are recognised as **potentially** causing significant effects on marine biota. In response to shell deformities of oysters, DPIWE conducted extensive sampling of sediment and oyster meat in Georges Bay. The bulk of the monitoring was conducted on a three-weekly basis from July 2001 to November 2002.

The highest sediment concentrations of TBT were located around slipyards and wharfs, with other sites sampled such as Medeas Cove and Lease 9 below detection limits. (Noller, 2003). TBT was also detected, albeit in low values, in feral Pacific oysters found around slipyards and wharfs. However, only on rare occasions was TBT detected in the oyster meat from leases in Moulting Bay, with concentrations always falling below detection (< 5 ng Sn/g) by the next sampling event. This suggests TBT levels are associated with short-term local phenomena, and there is not a concentrated source of TBT existing in Georges Bay (Mortimer, 2003).

Recently, the St Helens District High School conducted **total heavy metal** testing on the stormwater released into the Bay, the results of which are shown in Figure 21. Most total heavy metal concentrations were below detection levels regardless of flow, with only aluminium, chromium, iron and nickel recorded in storm water. With regard to the health of Georges Bay, both iron and nickel concentrations are very low compared with ANZEEC guidelines for these metals (ANZECC Water Quality Guidelines for aquatic systems are summarised in Appendix 2).

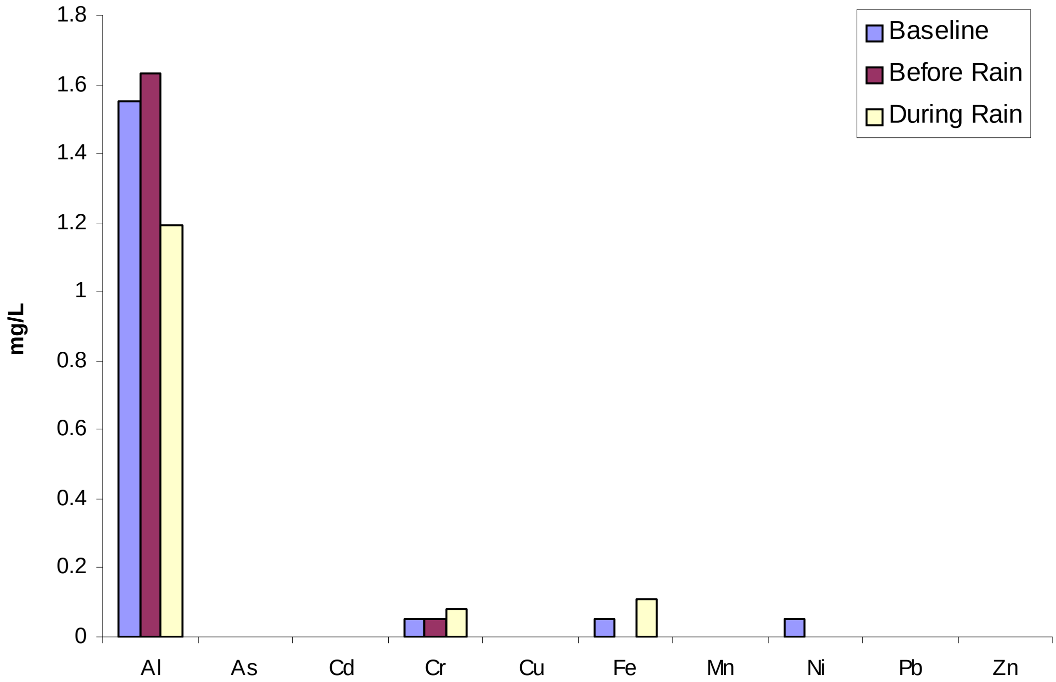

Figure 21. Heavy metals present in Georges Bay stormwater, October 2004

Total aluminium levels are elevated regardless of flow condition. Significant levels of aluminium are rapidly released from exposed granitic rocks and sand (Percival, 2004), which is the dominant bedrock in the Georges Bay catchment.

As some total metals are elevated above nationally accepted toxicant trigger levels, further investigation is necessary which will involve measuring both total and soluble metal levels. If levels are still significant it may be necessary to measure the speciated levels or alternatively accept the trigger values as being exceeded and conduct further investigation to optimally manage the situation by understanding the exceedance and develop strategies to manage it.

Targeted Pathogen Counts

Targeted pathogen counts have been conducted by many different groups on many different areas of Georges Bay. Levels of faecal coliform are monitored to provide an estimate of the total bacteria. The bacteria levels in Georges Bay are influenced by the freshwater loading from the George River, stormwater run-off from the shores of the Bay and release of sewage from the sewage treatment plant.

The recreational water quality of Georges Bay is monitored by the Break O'Day Council every summer. Thermotolerant coliform and enterococcus counts are conducted upon samples taken fortnightly for the December-March period. Satisfactory levels for primary contact activities such as swimming and boating are median values over the bathing season of $\leq$150 total faecal coliform/100mL (minimum of five samples taken at regular intervals over one month and four out of five samples must be <600 total coliform/100mL), and $\leq$35 enterococci organisms/100 mL (maximum number in any one sample between 60-100 organisms/100 ml). All sites recorded were within this limit (Figure 22).

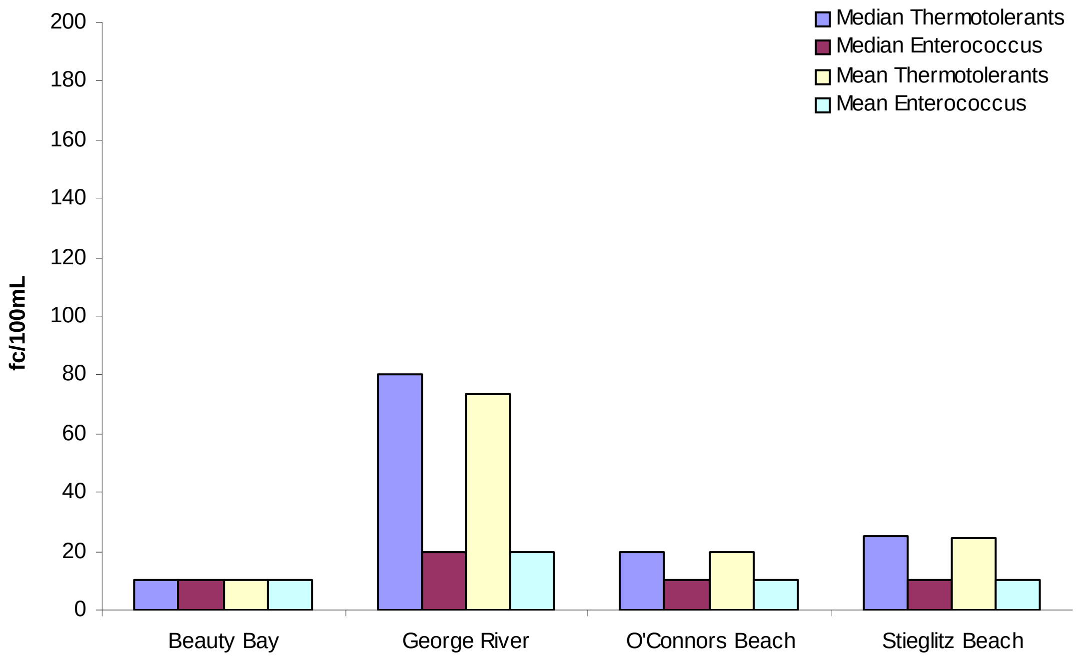

Figure 22. Recreational water results from summer 2004/2005

In the past individual recreational water quality samples have shown high faecal coliform readings, particularly at the Stieglitz beach site. However, the majority of samples recorded recently by SKM within Georges Bay were quite low. Nevertheless, there were occasional very high levels of faecal coliform; for example, at Lord’s Point in April 2005 values around 900 fcu/100 ml was recorded (Figure 23). The exception to these generally low values recorded by SKM is the “Bridge” site at the mouth of the George River, where satisfactory levels for primary activities were frequently exceeded. However, as samples recorded around Georges Bay proper at the same time were generally quite low, it is assumed that some dilution of coliforms occurs. Break O’Day Council suggests that high values recorded are closely related to periods of rainfall. However, other factors may also be important in the rate of decay of bacterial numbers, including the ‘biocidal nature of the saline receiving environment, predation, competition, residence time and intensity of ultra violet light.

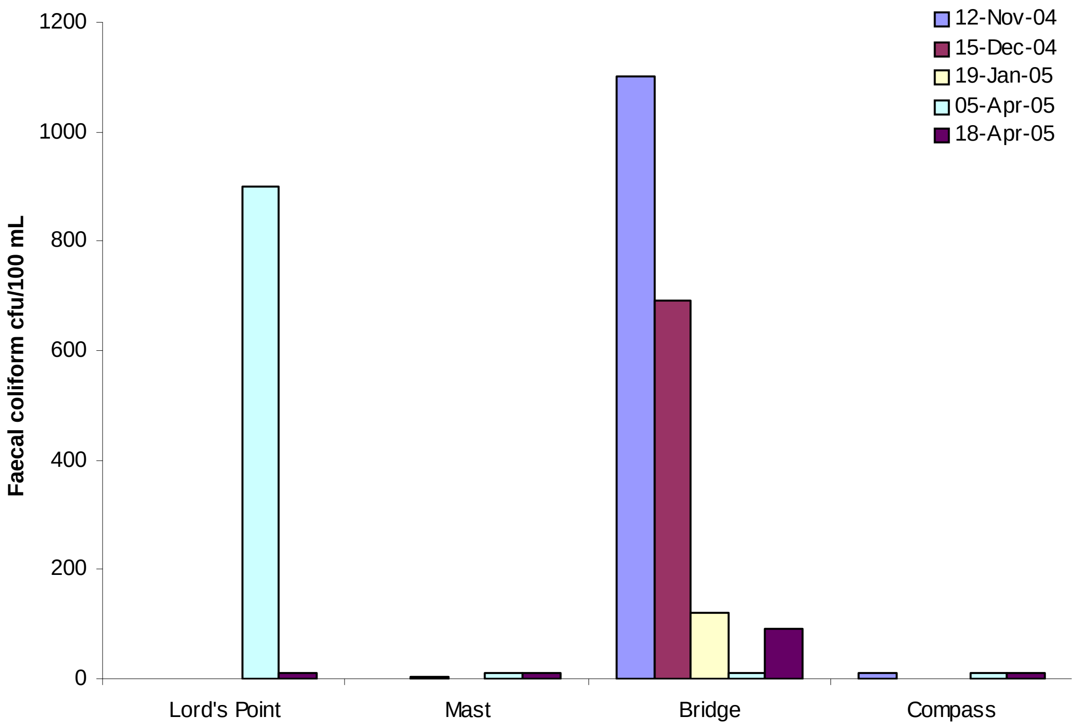

Figure 23. SKM faecal coliform results for Georges Bay

The St Helens stormwater was also monitored by the Break O'Day council six times over 2001 for total coliform (number of faecal and non-faecal coliforms) that are common in the natural environment, but are not necessarily indicative of human pathogens (Table 2). There are several samples that recorded values well above ANZECC guidelines of 150 cfu/100 mL and 1000 cfu/100 mL for primary and secondary activities respectively. Again, these high values were often linked to rainfall (T. Walker, BODC, pers. comm), when runoff from urban areas carrying faecal material from dogs, cats and wildlife, combined with leakage from under-performing septic systems is likely to contribute significantly. Break O'Day Council has been remediating this problem by converting nearly all residential properties in the Georges Bay area on septic tanks to the main sewer. However, the relevance of storm water data collected in 2001 to the current situation is not known.

Table 2. Total faecal coliform levels of the St Helens stormwater throughout 2001.
NS – No Sample taken at this site

	17/01/01	**22/02/01**	**22/03/01**	**18/07/01**	**27/08/01**	**18/12/01**
Jason St	6000	100	700	60	800	240
Lawry Heights	1600	56	50	40	34	130
Kirwans Beach	4	60	2900	20	36	56
*Osprey Drive**	3200	NS	NS	NS	NS	NS

*Open Drain

Despite an elevated total coliform input to the bay through stormwater, which is indicative of high pathogen levels, it is probable that dissipation and degradation of faecal coliform occurs in the saline waters of the Bay. This is supported by the recreational water quality results, which tend to return to background levels within a fortnight of elevation, providing there is no more rain. There has been no further monitoring of coliforms in stormwater conducted by Break O'Day Council since

2001. It should be noted that one of the objectives of this report is to inform Council and the community of the most appropriate stormwater testing regime in the future. Counts of faecal coliforms/thermotolerant coliforms and enterococci, however, are generally better measures of human pathogens than total coliforms,

TSQAP also frequently monitor faecal coliform levels in the Bay, in conjunction with rainfall and salinity. For example, throughout 2004, TSQAP monitored total faecal coliform at 16 different sites on five separate occasions. Not surprisingly, the highest values were recorded around the sewerage treatment plant outfall pipe, with 800 fc/100 mL recorded in June. Sites in Moulting Bay generally recorded higher levels of coliform than those in Georges Bay proper.

Due to the direct relationship between the mixing of freshwater with saltwater and salinity levels, TSQAP can use salinity as an indicator of faecal coliform levels in the water (Brown & Turnbull, 2003). Closure of leases from harvest occurs if the salinity levels drop below 29-31 ppt, as at this point, levels of faecal coliform may have reach a level unfit for harvesting of oysters. There were many closures of oyster leases in 2004, the most significant following the heavy flood in January (Figure 24). Not suprisingly, oyster lease zones near the mouth of the George River tend to suffer from more closures than zones on the eastern side of Moulting Bay. Zone 6, which incorporates the Wild Harvest Area 2 and the oyster leases at the entrance of Georges Bay, recorded the smallest number of closures in 2004, and is likely to be the site least affected by the George River.

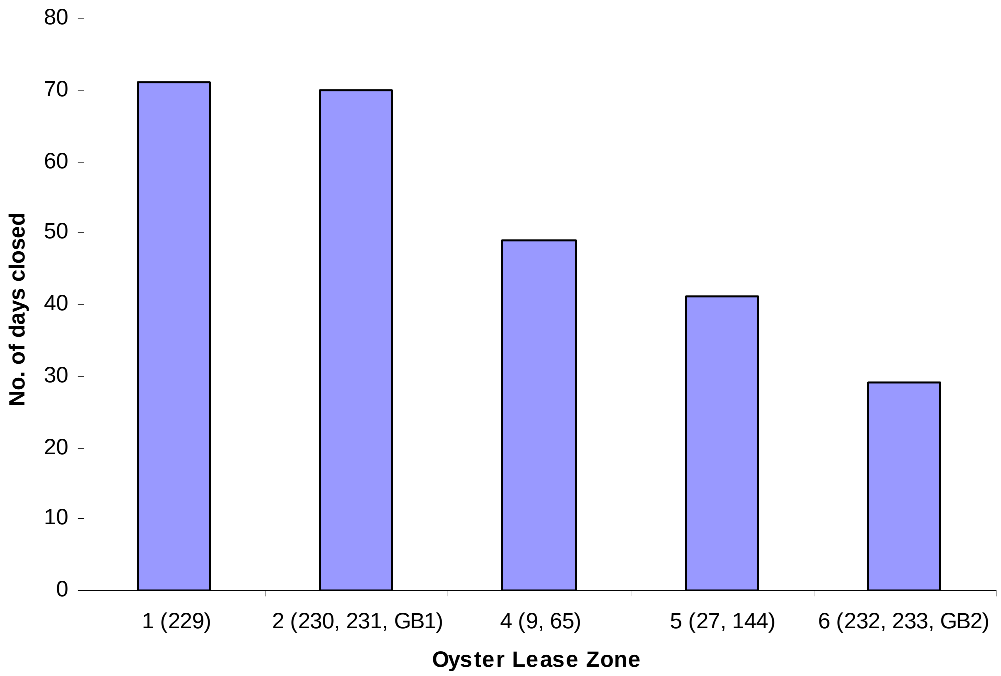

Figure 24. No of days Georges Bay oyster leases were closed from harvest, 2004

Monitoring of faecal coliform by Break O'Day council and TSQAP is ongoing.

Comments on usefulness of the data (time interval, reliability, useful indicator etc).

It is obvious from Table 1 that water quality data have been collected by a wide variety of groups, measuring different variables and over differing time periods. The longest data set is from the monitoring of shellfish farms which has been conducted by the Tasmanian Shellfish Quality Assurance program since 1983. However, these data are collected for a specific purpose and do not include some of the standard indicators of ecosystem health, such as nutrients, dissolved oxygen, turbidity or chlorophyll a. The majority of the sampling for water quality has been over short time periods or single sampling events. Additionally, the data have not been centralised into one database, nor any comparisons of results between the different studies or over time. As a consequence, the water quality of Georges Bay has not been systematically assessed. This report is intended to establish a regime to fill these gaps.

Comparison with results from other estuaries in Tasmania

Murphy et al (1999) surveyed the water quality of 22 estuaries around Tasmania and developed a draft set of indicator levels for four water quality parameters (Fig 25). As already mentioned, the only turbidity measurements from Georges Bay were in the low category and average chlorophyll a values for 11 months of sampling in 1993/94 were low in 4 months, medium in 4 and high in 3 months of sampling. Nutrients - NOx values in 1993/94 were low for the majority of the months sampled, medium in 2 months and high in one month, especially in the lower estuary. In 2004/05 NOx values were again mostly low except for one very high reading at the sampling sites in the estuary. Phosphate concentrations were in the low – medium category.

The important biologically available forms of nitrogen, NOx and ammonia, and phosphorous have been monitored at Little Swanport from January 2004 to February 2005 on a monthly basis and during flood events, two of which occurred during this period (Crawford et al, unpublished data). The range in values recorded from a marine site approximately 1 km from the estuary mouth and the uppermost estuarine site are presented in Table 4 as a comparison to Georges Bay. Monthly NOx concentrations at Georges Bay were generally similar to those at the Little Swanport, except for a considerable higher peak at Georges Bay marine site in July 2003 than at the marine site at Little Swanport. The peak estuarine flood values for NOx were much higher at Little Swanport than at Georges Bay in 1993/94 and were similar to the peak values at the Bridge site at Georges Bay in June 2005. Phosphate concentrations were generally similar at the two estuaries and values for ammonia were mostly low at both sites except for peaks on several occasions, especially at georges Bay in November 2004 on several occasions above the maximum concentrations recorded in southern Tasmania.

			Sample						
Bioregion	**Estuary**	**Parameter**	**JA99**	**SO99**	**ND99**	**JF00**	**MA00**	**MJ00**	**median (JA99-MJ00)**
Boags	Duck Bay	Turbidity	21.0	17.6	7.0	8.7	6.0	12.2	8.3
		Chlorophyll a	2.9	2.0	1.4	1.4	1.5	1.7	1.5
		NOx	289	268	165	39	93	235	127
		PO4	104	30	27	30	17	15	28
	East Inlet	Turbidity	2.1	2.8	1.1	1.9	0.9	1.7	1.7
		Chlorophyll a	0.1	0.0	4.4	0.6	0.0	0.2	0.0
		NOx	5	3	1	1	2	3	2
		PO4	20	12	8	10	11	11	11
	Black River	Turbidity	8.9	3.9	3.8	3.0	2.9	3.1	3.4
		Chlorophyll a	0.2	0.1	0.8	0.9	0.7	0.2	0.4
		NOx	95	62	48	24	48	55	57
		PO4	5	6	3	9	5	1	4
	Don River	Turbidity	50.0	9.8	125.3	no data	8.1	4.5	8.6
		Chlorophyll a	2.5	0.7	25.6	17.6	0.7	0.1	0.8
		NOx	1125	328	20	5	31	343	118
		PO4	8	4	31	11	13	8	9
	Mersey River	Turbidity	12.0	3.6	13.3	no data	6.3	3.1	5.5
		Chlorophyll a	0.8	0.3	3.1	0.9	0.7	0.2	0.5
		NOx	289	65	19	24	22	61	31
		PO4	8	8	9	15	13	10	11
	Port Sorell	Turbidity	39.9	6.6	5.4	no data	4.8	3.1	5.4
		Chlorophyll a	1.3	1.2	1.6	0.9	0.5	0.3	0.8
		NOx	217	5	0	2	4	11	4
		PO4	12	22	9	8	9	6	8
	Boobyalla Inlet	Turbidity	16.9	13.2	4.2	4.5	4.2	8.2	6.9
		Chlorophyll a	1.7	1.4	0.8	4.1	1.1	0.8	1.2
		NOx	250	277	132	72	18	158	138
		PO4	9	6	1	2	3	2	2
	Little Musselroe River	Turbidity	4.0	5.4	1.6	6.7	3.5	3.9	3.4
		Chlorophyll a	1.6	0.6	0.0	33.2	2.5	2.0	1.1
		NOx	16	24	1	2	1	13	4
		PO4	8	7	4	17	4	6	6
Freycinet	Ansons Bay	Turbidity	1.4	2.6	1.8	5.3	1.7	0.8	1.7
		Chlorophyll a	20.3	8.8	5.7	11.2	7.5	2.2	5.3
		NOx	5	4	1	14	2	3	2
		PO4	10	6	3	10	14	12	8
	Grants Lagoon	Turbidity	1.2	1.3	2.7	2.2	1.7	1.2	1.5
		Chlorophyll a	1.3	1.0	0.4	3.0	1.2	0.8	1.2
		NOx	17	3	0	1	2	38	1
		PO4	4	2	3	3	2	2	2
	Douglas River	Turbidity	8.0	1.4	1.6	2.1	1.4	2.1	1.7
		Chlorophyll a	0.1	1.0	0.7	0.0	0.3	0.0	0.0
		NOx	11	0	11	178	75	62	24
		PO4	1	2	2	3	2	8	2
	Great Swanport	Turbidity	1.7	1.5	1.6	1.5	1.4	1.8	1.4
		Chlorophyll a	0.3	0.4	0.1	0.9	0.6	1.0	0.5
		NOx	0	2	0	2	1	0	1
		PO4	6	3	2	4	5	2	3
	Meredith River	Turbidity	14.8	0.9	2.5	3.4	3.5	0.9	2.6
		Chlorophyll a	6.0	2.2	8.8	3.2	10.0	0.8	1.9
		NOx	124	6	1	56	3	6	6
		PO4	5	2	3	6	4	2	2
	Little Swanport	Turbidity	1.8	1.5	2.1	2.3	3.3	2.1	1.8
		Chlorophyll a	0.7	0.3	1.2	2.4	6.1	1.1	1.1
		NOx	3	1	0	0	0	2	0
		PO4	6	4	3	3	5	4	4
	Earlham Lagoon	Turbidity	3.7	1.8	2.0	2.1	3.0	0.9	2.0
		Chlorophyll a	0.9	0.2	0.5	0.8	0.6	0.1	0.4
		NOx	28	1	1	5	1	2	2
		PO4	9	6	6	5	6	6	6
Bruny	Browns River	Turbidity	56.0	1.8	3.9	5.0	5.1	3.1	3.2
		Chlorophyll a	2.4	0.7	2.5	7.0	9.2	4.7	2.6
		NOx	332	8	3	1	1	10	5
		PO4	8	14	25	13	42	17	16
	Cloudy Bay Lagoon	Turbidity	1.2	0.9	1.4	1.1	1.0	1.4	1.0
		Chlorophyll a	2.3	0.9	0.3	0.9	0.6	1.0	0.7
		NOx	7	4	0	2	1	13	1
		PO4	6	4	5	9	5	9	6
Davey	Catamaran River	Turbidity	3.1	1.2	1.2	2.0	1.1	2.0	1.5
		Chlorophyll a	0.0	0.6	0.5	0.1	0.1	0.0	0.0
		NOx	13	9	0	1	6	9	5
		PO4	4	7	5	5	5	4	5
	Cockle Creek	Turbidity	3.5	1.0	1.3	1.3	1.6	1.5	1.4
		Chlorophyll a	0.7	1.2	0.6	0.1	1.1	0.8	0.4
		NOx	22	5	1	1	1	7	2
		PO4	5	7	2	4	3	3	4
Franklin	Pieman River	Turbidity	2.9	9.8	1.8	1.6	4.6	2.6	2.6
		Chlorophyll a	0.0	0.0	0.0	0.1	0.2	0.0	0.0
		NOx	28	22	36	20	21	19	23
		PO4	1	0	0	2	0	0	0
	Nelson Bay River	Turbidity	6.2	10.7	5.9	4.2	1.3	3.1	5.2
		Chlorophyll a	0.0	0.1	0.0	3.4	1.5	0.0	0.0
		NOx	13	7	8	2	3	8	7
		PO4	2	1	1	8	5	2	2
	Arthur River	Turbidity	10.5	5.2	8.2	2.5	2.9	4.3	4.5
		Chlorophyll a	0.0	0.1	0.0	0.6	0.1	0.0	0.0
		NOx	39	17	10	5	9	20	13
		PO4	3	1	1	2	0	1	1

Draft (indicator levels)		**low**	**medium**	**high**	**very high**
Turbidity	NTU	0 to 4	4.1 to 10	10.1 to 20	> 20
Chlorophyll a	µ g/L	0 to 2	2.1 to 5	5.1 to 10	> 10
NOx	µ g/L	0 to 20	21 to 50	51 to 100	> 100
PO4	µ g/L	0 to 5	6 to 15	16 to 30	> 30

Figure 25. Draft indicator levels for water quality parameters in Tasmanian estuaries (from Murphy et al., 1999).

Table 4 also contains the recommended values for water quality from ANZECC guidelines. Note that these guideline values for estuarine and marine nutrients were not based on any Tasmanian water quality data and so should be used with caution. However, the ANZECC guideline values for other water quality parameters (listed in Appendix 2) are applicable to Tasmanian conditions. NOx values at Georges Bay in 1993/94 were above the ANZECC recommended estuarine concentration on 3 out of 11 months of sampling and phosphates in every month sampled. Almost half the NOx and one quarter of NH4 concentrations recorded in 2004/05 were above the ANZECC guidelines for estuaries. It is noted that NOx values at the marine site just outside the Bay were higher than ANZECC guideline values on several occasions, indicating oceanic input of nutrients and that ANZECC guidelines are not always applicable to Tasmanian nutrient conditions.

Table 4. Water quality values from Little Swanport January 2004 – February 2005 and recommended ANZECC guidelines. ANZEEC guidelines for other water quality parameters are listed in Appendix 2.

WATER QUALITY MEASUREMENTS ($\mu g.l^{-1}$)	**Estuarine (all sites)**	**Marine (A – deep)**	**ANZECC estuarine/marine**
NOX			
Monthly samples	2 - 42	2 - 25	15 / 5
Flood events	189 - 293	17 - 48	
NH_4			
Monthly samples	8 - 24	7 - 20	15/ 15
Flood events	37 - 150	14 - 39	
PO_4			
Monthly samples	2 - 5	3 - 8	5 / 10
Flood events	5 - 6	3 - 7	

Assessment of the health of the bay.

The limited environmental data available collected over the last two decades that has been summarised in the preceding pages suggests that the bay is in reasonable health. Nutrient concentrations were mostly low, no herbicides, pesticides or TBT were detected in the water or animal flesh, chlorophyll a values were generally below bloom conditions and seagrass and fish populations, which are recognised indicators of environmental condition (Ward et al, 1998), are indicative of a healthy estuary.

However, most of the sampling for water quality was conducted during normal conditions and the limited data available during rainy periods and after flood events indicates significant deterioration of water quality can occur during and after these events. The high faecal counts on occasions indicate that the current sewage treatment system is not meeting acceptable standards during these events. Significant organic enrichment near the sewage outfall is obvious from the changed population of benthic infauna to capitellidand spionid polychaetes, classic indicators of increased organic input. Levels of BOD at the outlet site are also well above recommended maximum emission values. Very high levels of faecal coliforms, mostly near the sewage outfall and especially after rain, further imply that the existing infrastructure is not adequate to meet demand during peak periods. This should change, however, with the installation of the new waste water treatment plant for St Helens, which consists of tertiary treatment membrane bio-reactor technology and capacity for water reuse.

The water quality at storm water outfalls has not been monitored since 2001, which is a significant gap in information. The stormwater during flood events can result in diffuse pollutants such as nutrients, suspended solids, metals and faecal coliforms entering waterways and the estuary. These inputs impact of water quality and associated environmental values. Occasional high values for nutrients, especially ammonia and phosphates, and chlorophyll a, which imply a bloom of microalgae, are also evidence of excessive nutrient inputs. Highly turbid conditions observed in Moulting Bay on occasions, which are consistent with seagrass maximum depth distributions, also suggest potential problems.

Options and Considerations for monitoring and assessment of the health of the Bay

Background to the development of a monitoring program

What to monitor, and where and when, to assess the condition of an estuary is a complex issue. Because of the dynamic nature of estuaries, with constant contribution from oceanic waters and from freshwater inflows, there is no one single parameter that can effectively describe the state of an estuary. This is further exacerbated by the enormous fluctuations in freshwater flows between normal and flood based events. Thus a number of parameters need to be measured to give an overall picture of estuarine health. Information on flow patterns in an estuary are also important to understanding the impact that pollutants, nutrients etc can have on the estuary. For example, if nutrients are rapidly flushed out to sea the consequences will be much less than when nutrients are retained in the estuary and available to micro and macro algae.

Periodic measurements of water column variables, for example nutrients every month, is common in many monitoring programs, but this practise is problematic because water quality parameters can vary by orders of magnitude during this time period. For example in Little Swanport estuary nitrate values have risen as high as 270 μgl^{-1} during a flood and dropped back to 82 μgl^{-1} after 5 days and to 3 μgl^{-1} one month after the flood. This is a well recognised problem. However, reasonably priced and reliable automatically monitoring systems for most water column parameters are not yet available, except for temperature and salinity. Testing for many chemicals, including nutrients, heavy metals and herbicides and pesticides, in specialised analytical laboratories is expensive and sample numbers are limited by the funds available. Thus a monitoring program is often a compromise between the number of samples required for comprehensive statistical assessment and money available to the program.

In any monitoring program it is essential to have detailed baseline information as the basis for assessing change in environmental condition. Because of limited data available for most estuaries, baselines often have to be set at the current condition. Even though we know many estuaries have changed markedly over the last 200 years of European settlement because of human activities such as land clearing, farming activities, increase in human waste products etc, we do not have sufficient quantitative data on which to assess change; it is almost entirely anecdotal. Thus detailed baseline data are generally being collected now, and a monitoring program developed from this baseline. The monitoring program usually consists of a reduced number of parameters and sampling frequency to the baseline, but if a decline in condition is suspected, then more detailed sampling, similar to the baseline, is generally required.

Biological indicators are often included in monitoring programs because they:

- Provide information on the ecology of the system and on the values we place on a healthy, functioning ecosystem. They indicate whether stressors to a system, such as increased pollutants, are impacting on the natural flora and fauna;
- They can be good indicators of multiple stressors on an estuary. Resident species are integrators of all the various factors that contribute to poorer water quality. The combination of several pressures, for example different chemicals

and increased sediment loading, can have a different effect to the sum of individual pressures. The condition and size of seagrass beds and abundance of different species of invertebrate fauna in the sediments are two common biological indicators of estuarine health.

Community and Expertise-based monitoring programs

A monitoring program for Georges Bay is recommended at two levels:

1. a community monitoring Program, and
2. an expertise-based monitoring program.

The objectives of a community-based monitoring program have a different emphasis to those of an expertise-based monitoring program, but they are often confused. A community-based monitoring program should not be considered a full substitute for an expertise-based program, and vice versa. Community monitoring is a very valuable resource but it is dependent on volunteer participation and should not be expected to replace monitoring requirements of industry users and governments.

Community-based monitoring has a major component of participation, education, and awareness raising amongst the general population, and as such may include environmental parameters that are considered to be of high interest to the broader community. They also generally aim to provide environmental information that is beneficial to improved management of an area, especially to local and regional management agencies, but mostly at a reduced level of detail and fewer parameters. Community groups may also conduct targeted short-term investigations such as fish catch information, coastal weed mapping and removal or collecting environmental data from an area that they consider is under threat of degradation.

Expertise-based monitoring generally has a specific objective in mind, such as monitoring in relation to the performance of a wastewater treatment plant or the impact of heavy metals and other industrial wastes on the health of an estuary, such as in the Derwent estuary. There is a detailed sampling procedure and parameters monitored are specific to the issue being addressed. Most of the parameters require some scientific expertise and analysis in an accredited laboratory.

Nevertheless, community and expertise based monitoring have important benefits to each other and should be conducted in close co-operation, and preferably as one monitoring program which co-ordinates the community and expertise based monitoring programs together, but at the same time maintains the objectives of the two programs. The time and place of sampling should be synchronized where possible to maximize the information available from both programs and the monitoring results lodged in a centralized database where they are readily available to all interested parties.

Monitoring the health of an estuary ideally consists of a well coordinated mix of community and expertise-based monitoring, with the community involved in monitoring easily measured environmental parameters and keeping records of significant events (such as algal blooms, fish kills). Expertise-based monitoring should be coordinated by local council and involve the parameters that require specialist knowledge and funding for analysis, such as nutrients.

Community Monitoring Program

Background to development of community-based monitoring:

This program is based on limited scientific knowledge of volunteers and a reduced level of training to collect and evaluate the results. It is also relatively inexpensive to conduct once the essential equipment has been purchased. One of the main advantages of community-based monitoring is that the people involved are generally on site and can conduct monitoring during special events, such as during and after flood events, oyster or fish kills etc. Community monitoring can be an important early warning system to management for emerging problems.

Community-based monitoring has increased significantly in the last decade, largely through the funding and support provided by the Australian government through the Waterwatch organisation. This program has concentrated on community-based groups monitoring freshwater systems and there is currently increasing interest on community monitoring of estuaries.

The Waterwatch Australia Steering Committee is in the process of preparing a Waterwatch National Technical Manual which is being published in a series of modules. Modules 1 – 4 are already available:

1. Background
2. Getting Started: the team, monitoring plan and site
3. Biological Parameters,
4. Physical and chemical parameters.

Modules 5 Data.. Information..Action! and 6 Waterwatch and Schools are at the printers.

Module 7 is on Estuarine Monitoring and a National Community Estuarine Monitoring workshop was held in Sydney on July 27-28 2005 to facilitate the development of this module. The workshop brought together people involved in community-based estuarine monitoring (scientists, community, Waterwatch Coordinators, State and Territory Officers) to discuss and agree on a national framework for community estuarine monitoring. Existing work developed in a number of States and research institutions was used as the basis for the framework. The framework includes estuarine monitoring indicators and methods and units of measurement. Dr Christine Crawford from TAFI attended this workshop and recommendations made below for community monitoring of Georges Bay are based on the discussions from this workshop. As the final outcomes of the workshop have not yet been distributed, minor changes to the recommended monitoring program may be required. TAFI will provide relevant additional information to the Break O'Day Council when details of Module 7 become available, most likely in Waterweek in October 2005.

Indicators recommended by the National Community Estuarine Monitoring Workshop include:

- Background and contextual information - estuary map, estuary classification, time and tide height, surface water conditions, weather, water colour and odour, water depth and flow events,
- Estuarine processes – water temperature, salinity, pH, water clarity (turbidity), estuarine mouth open/closed
- Chemical – dissolved oxygen, nutrients
- Vegetation and habitat – presence of algal blooms, chlorophyll a, seagrass percentage cover and depth range, intertidal macrophytes/macroalgae, submerged macrophytes/macroalgae, beach litter, saltmarsh percentage area
- Animal life – rocky shores snails, crab burrows in tidal flats, presence/absence of invasive species, bacteria, records of animal kills and disease/lesions including animals killed or entangled by litter and death of marine mammals.

Indicators that are obviously not relevant, such as mangroves, have been deleted from this list.

Indicators for community monitoring of Georges Bay:

1 Background information - estuary map and estuary classification has already been conducted by TAFI. Detailed information on Georges Bay is presented in the associated TAFI report 'Bringing Back the Bay: Habitats and Water Quality in Georges Bay' by Richard Mount et al (in prep.).

2 Contextual information:
Date, time, tide height, surface water conditions, weather, colour and any unusual odours should be recorded at each sampling site on each sampling trip. If possible sampling should be conducted at the same stage of the tide on each occasion, and preferably on an ebbing to low tide.

3 Estuarine processes:

Water temperature, salinity, and pH can be measured using hand-held field probes, preferably held just below the surface and just above the bottom (although this will depend on the length of cable with the field meter).

Salinity profiles , i.e. measures of salinity through the water column, at several sites in the estuary are very useful in understanding water movements through the bay.

Water clarity (turbidity) can be measured using a turbidity meter although these are reasonably expensive. A relatively good and inexpensive measure of water clarity can be obtained using a Secchi disc which could be made locally (TAFI can provide information on constructing and using a Secchi disc if required).

4 Chemical:

Dissolved oxygen can be measured using a field probe and preferably just below the surface and just above the bottom. A clear sign of deteriorating water quality is low DO in bottom waters.
However, our experience is that DO probes are temperamental and difficult to maintain for any length of time. Also, DO must be calculated according to the temperature and salinity of the seawater. DO probes must be carefully maintained and regularly calibrated. They will also require annual servicing by an accredited instrument repairer.

Chlorophyll a and nutrients will need to be analysed in an accredited laboratory, such as Analytical Services Tasmania. They are relatively expensive (approx. $50/sample for Chl a, and $150/sample for measurement of NOx, NH3 and PO4, the minimum set of nutrients for monitoring estuarine health). A reduced price can be negotiated for a large number of samples.

Note: field colorimeters and spectrophotometers are being used in other Australian states to measure nutrients by Waterwatch groups; however these portable instruments generally have a minimum detection limit of $20 \mu g l^{-1}$, which is above the DPIWE recommended target for these nutrients in Georges Bay. Thus, these and other nutrient field monitoring kits would only be suitable for recording high levels of nutrients, such as after flood events.

Community groups would be able to collect samples for testing in approved labs provided they are trained in appropriate water collecting methods and funding is available to pay for the laboratory analyses. Some nutrients, especially ammonia, are extremely sensitive to contamination and for example, must be collected by non-smokers because nicotine on fingers can contaminate a water sample.

5 Vegetation and habitat:

Records should be kept of obvious algal blooms in the bay, including where, when and colour of the algal bloom.

Monitoring seagrass beds is commonly conducted by community groups in other Australian states where the water is warmer and detailed methods have been developed. At the simplest level this involves determining the area and location of beds and the maximum depth to which the beds grow. More detailed monitoring includes recording the density of plants and the length of seagrass blades etc. Descriptions of these monitoring methods are available on the internet and are not repeated here. An excellent example is Parks Victoria Technical Series No 16. Sea Search: Community-Based monitoring of Victoria's Marine National Parks and Sanctuaries Seagrass Monitoring , 2005 available at: http://www.parkweb.vic.gov.au/resources/19_1326.pdf
Methodology of sampling will also be described in Module 7 of the National Waterwatch manual.

Monitoring intertidal macrophytes/macroalgae is also conducted by many community groups. This involves measuring the percentage cover of algae and the size and location of the bed. The major algal species should also be identified (such as sea lettuce - *Ulva* sp, Neptune's necklace – *Hormosira banksii*, green slimey algae – *Enteromorpha compressa* etc)

A simple method for monitoring intertidal seagrass and macroalgae is to take good, clear photographs of the intertidal zone at low tide at designated locations at regular intervals, such as seasonally. The photographs should contain an indication of scale. More complex and detailed methodology for monitoring intertidal and subtidal macroalgae will be provided in Parks Victoria Technical Series Nos 17 and 18 and in the Waterwatch Technical Manual Module 7 when they become available. These manuals generally recommend seasonal monitoring of seagrass beds to take into account seasonal variation. However, annual monitoring would be sufficient, provided the monitoring is conducted in the same season each year.

It should be noted, however, that algal blooms, seagrass and macroalgae naturally cycle, i.e.'boom or bust' events, in Tasmanian coastal and estuarine waters. For example, the common subtidal seagrass in many Tasmanian estuaries, *Heterozostera tasmanica*, has been observed to fluctuate markedly, with no obvious anthropogenic activities involved. This is different to mainland beds of *Posidonia* species of seagrass, which have very stable populations unless disturbed. Similarly, bright pink blooms of the microalgal species *Noctiluca* have been observed in eastern and southern Tasmania. This is a naturally occurring species and no clear links between blooms and degraded conditions have been identified.

Saltmarsh communities are generally considered to under threat in Tasmania; however little information is available on their size or species composition. The area of saltmarsh regions can be easily monitored from aerial photographs and groundtruthing the size, density and location of the saltmarsh.

Some community groups may like to take periodic measurements of the amount of litter in the bay. This is an indicator of social patterns and amenity of the area, but not the environmental condition of the bay.

6 Animal life:

Animal kills in the bay, such as fish kills and major oyster mortalities should be documented by community groups. Records should also be kept of any animals with clear signs of disease or lesions. This includes any animals that are killed or entangled in litter. Similarly, the death of any marine mammals in the bay should be recorded.

The distribution and abundance of rocky shore snails and intertidal crab burrows have been found in other Australian states to be useful indicators of estuarine health which are suitable for community monitoring. As there is limited information on either rocky shore snails or intertidal crab burrows in Georges Bay, the value of these parameters as indicators of estuarine condition would need to be first assessed before incorporating them into a community monitoring program. Details of sampling methodology for these parameters will be provided in Module 7.

Bacterial pathogen counts can be conducted by community groups using test kits available from suppliers of scientific equipment. Details of the procedure is provided in Module 7 and on the test kits. However, these kits can provide variable results and should be used only as an pointer towards bacterial problems. Accurate information on bacterial concentrations requires testing in accredited laboratories and this is currently being conducted by TSQAP and Break O'Day Council.

Where to sample and when

Where possible, the location of sample sites and frequency of sampling should be coordinated between community and expertise-based monitoring programs (see section under expertise-based monitoring).

However, a community based monitoring program will also be determined by the objectives and availability of the volunteers involved. They may also have specific sites that they wish to monitor which are outside a coordinated community-expertise based monitoring program, because, for example, they have specific concerns about a site, it is in their neighborhood etc.

Quality assurance

Waterwatch has developed methods for coding the level of accuracy and confidence of community collected data, depending on the level of training, accuracy of the equipment used and regularity of calibration of equipment, and this methodology should be followed.

All Waterwatch participants receive training in monitoring and are given a choice of the level of data confidence and level of accuracy that they wish to monitor at. If the volunteer follows the protocols in the Waterwatch manual and calibrates the equipment (mostly hand held probes) every 2-3 months, the data is rated as being within $\pm$ 10% accuracy. If the volunteer receives additional training, generally has more sensitive equipment (better quality field meters) and calibrates the equipment every time before use, the data is rated as being within $\pm$ 5% accuracy.

Expertise-based Monitoring Program

Background to the development of an expertise-based monitoring program:

The indicators recommended for this program include environmental parameters that require some scientific knowledge and training to collect and assess the results. Many are also expensive to process, either at Government analytical laboratories (e.g. for nutrients, heavy metals, herbicides and pesticides) or specialised private laboratories (e.g. for identification of invertebrate fauna).

A Tasmanian Coastal, Estuarine and Marine Indicators Working Group was established in early 2005 to recommend a suite of indicators for monitoring the condition of representative coastal, estuarine and marine environments in Tasmania. These indicators will meet the Natural Resource Management (NRM) monitoring and evaluation framework for coastal, estuarine and marine habitat integrity and are based on the indicators recommended by the Australian Government commissioned report by the Coastal CRC (Cooperative Research Centre) 'Users Guide for Estuarine, Coastal and Marine Indicators for Regional NRM Monitoring'.

The Tasmanian CEM Indicators Working group consists of experts from various government departments, research organizations including the University of Tasmania and CSIRO, consultants and industry representatives. This group has agreed on a subset of indicators, recognising that a unrealistic 'wish list' of indicators would probably never be funded, and that indicators should be chosen on the basis of being the most cost-effective measures of change in environmental condition. The number of indicators has been narrowed down to 14, although some indicators, such as extent of key habitat types, represent a broad range of possibilities for monitoring and will require further discussion and refinement by the Working Group. Currently the working group has divided into 4 subgroups (A - Water quality/Water chemistry, B - Habitat and biodiversity (Marine and estuarine), C - Habitat and biodiversity (Coastal and terrestrial) and D – Shoreline position), to facilitate further collection of information around the indicators. The indicators recommended so far and the information collected by the Tasmanian CEM Indicators Working Group will form the basis of recommendations for a monitoring program for Georges Bay. Again, as more information becomes available from the Working Group, TAFI will provide relevant additional information to the Break O'Day Council.

Indicators recommended by the Tasmanian CEM Indicators Working Group are:

A. Water quality/water chemistry –
    - chlorophyll a (if elevated consider identifying algal blooms)
    - dissolved oxygen
    - pH
    - salinity
    - thermotolerant coliforms
    - total nutrients in the water column (important wrt catchment input) and dissolved nutrients in the water column (important wrt biologically available nutrients (NH3, NO3+NO2, PO4, SiO4)
    - toxicants
    - turbidity/water clarity
    - water temperature
B. Habitat and biodiversity (estuarine and marine)
    - animal or plant species abundance
    - pest species (number, density, distribution)
    - Extent/distribution of key habitat types
C. Habitat and biodiversity (Coastal terrestrial)
    - animal or plant species abundance

- pest species (number, density, distribution)
- Extent/distribution of key habitat types

D. Shoreline position (including sediment/erosions and river or lagoon opening)

Indicators for expertise-based monitoring of Georges Bay:

A Water quality/water chemistry

Chloropyll a – is measured in a laboratory using a spectrophotometer. It is a good indicator of algal biomass.

Algal blooms – The concentration of microalgae through the water column can be measured by taking a water sample in a long plastic tube which is suspended in the water column. The density of algal cells in the water sample is measured under a microscope and the dominant species identified, particularly to determine whether there are problem species such as the toxic dinoflagellate *Gymnodinium catenatum* .

Dissolved oxygen, pH, salinity and water temperature – are measured using probes attached to field meters. Note: dissolved oxygen is dependent on salinity and temperature values, and field probes need regular maintenance and calibration. It is recommended that dissolved oxygen field probes are routinely checked using Winkler titrations (a standard and more accurate measure of dissolved oxygen conducted on samples in a laboratory). Profiling these environmental variables through the water column provides information important to understanding water movements within the estuary as well as the health of the estuary, and at minimum should be measured at the surface and near the bottom.

Thermotolerant coliforms and enterococci should be measured in an accredited laboratory, with samples collected according to a standard protocol and samples delivered to the laboratory within a prescribed time period. Because of the high levels of coliforms that have been recorded in Georges Bay on occasions it is important that they continue to be monitored on a regular basis and during flood events. At present thermal tolerant coliforms are being monitored monthly by council as part of the waste treatment plant upgrade and this should continue, as well as event-based measurement of coliforms.

Nutrients – the important biologically available nutrients (NH3, NO3+NO2, PO4) should be monitored routinely and during flood events. If funds permit, total N and total P should also be measured as indicators of catchment input into the estuary. Accurate measures of nutrients can only be obtained from accredited laboratories and a strict sampling protocol is required to ensure that samples are not contaminated during collection.

Toxicants are expensive to measure and generally are only routinely monitored if there is concern about high levels of contaminants, such as heavy metals or herbicides and pesticides being present in the water column. The need for testing for toxicants should be assessed by Council and the general community each year during an annual assessment of the health of the Bay.

Turbidity/water clarity is relatively easily measured using a nepholometer or more simply with a secchi disk and should be measured routinely and during flood events.

B Habitat and biodiversity (estuarine and marine)

Animal or plant species abundance - for Georges Bay, detailed monitoring of seagrass and invertebrate fauna are recommended as the two main biological indicators of ecological health of the Bay. Monitoring of these indicators requires technical expertise and as detectable changes generally do not occur quickly, it is recommended that they are monitored every 2-5 years. However, a comprehensive baseline at the commencement of monitoring is essential. Techniques for the monitoring of these indicators are currently being prepared by the Coastal, Estuarine and Marine Indicators Working Group and will be available towards the end of 2005. It is anticipated that this methodology will follow the standard protocols developed by TAFI for monitoring seagrass as part of the SeaMap Tasmania project and monitoring invertebrates as part of the assessment of salmon farm impacts and estuarine health in other estuaries around Tasmania.

Extent/distribution of key habitat types - similar to animal or plant species abundance indicators, techniques for monitoring the extent of key habitat types are currently being prepared by the Coastal, Estuarine and Marine Indicators Working group and will be available towards the end of 2005. This methodology will closely follow the standards protocols developed by TAFI for mapping habitat types as part of SeaMap Tasmania.

C Habitat and biodiversity (coastal terrestrial) is not covered here as the terms of reference related to water quality in the Bay.

D Shoreline position (including sediment/erosions and river or lagoon opening). Methodology for monitoring shoreline indicators is currently being prepared by the members of theCoastal, Estuarine and Marine Indicators Working Group and will be provided to Break O'Day Council when they become available.

Location of sampling

Sites recommended for monitoring physical/chemical parameters and invertebrate fauna in Georges Bay are a combination of sites monitored by Crawford et al (1999) and currently being monitored by SKM.

These are: Redflash
Lords Point
Mast
Humbug
Compass
Bridge

These sites are chosen to provide an overall view of the health of the estuary. They do not specifically relate to point sources of pollution such as storm water outfalls. If there are concerns about pollutants entering the bay from these point sources, then additional monitoring should be conducted at 50 m from the outfall.

Sites recommended for monitoring seagrass are those established in the baseline assessment of seagrass distribution and condition by TAFI and described in detail in the report ‘Bringing back the bay: marine habitats and water quality in Georges Bay (Mount et al, 2005). This includes sampling using quadrats, aerial photography and the deepest depth of seagrass beds.

Frequency of sampling

Water quality/water chemistry - monthly and during/after flood events (see Table 5)
Note: toxicants which will depend on requirements of community and council

Habitat and biodiversity - every 2-5 years

Event-based sampling, such as during floods, is very important to understanding the impact of land-based activities on the estuary and to quantifying the input of sediments, nutrients and potentially pollutants into the estuary during flooding.

Summary of monitoring requirements for Georges Bay

Table 5 summarises the recommended indicators and frequency of sampling to monitor the health of Georges Bay, based on the indicators recommended by the Waterwatch Australia Steering Committee and the Coastal, Estuarine and Marine Indicators Working Group in Tasmania. This table also lists whether sufficient baseline data are available against which to measure change in environmental condition.

Clearly, baseline data are required for several parameters, including turbidity, pH, DO, saltmarsh area and algal blooms. The table also summarises separately parameters for community and for expertise-based monitoring, and frequency of sampling for ongoing monitoring, including event-based sampling.

A major challenge for stakeholders of Georges Bay will be to secure the resources required, both financial and human, to complete the baseline assessment and to continue monitoring. The community, Break O'Day Council and State Government will need to work in close cooperation and all contribute to the process so that sufficient resources are available to routinely assess the condition of Georges Bay. This is essential to maintaining the exceptional natural assets of Georges Bay and the sustainability of the Bay community.

Table 5. Recommended Monitoring Program for Georges Bay

Monitoring program for Georges Bay

Parameter	Baseline data	Ongoing monitoring	Event monitoring	Community monitoring	Expertise monitoring
Temperature	yes	monthly or automatic	yes	yes	yes
Salinity	yes, limited profiling	monthly or automatic	yes	yes	yes
Turbidity	no	monthly or automatic	yes	yes	yes
Dissolved oxygen	no	monthly or more frequent	yes	yes	yes
pH	no	monthly	yes	yes	yes
Chl a	some	monthly	yes	?	yes
algal blooms	no	monthly, if funds available		yes	yes
NOx, NH4, PO4	some	monthly	yes	?	yes
TN, TP	some	monthly, if funds available	yes	?	yes
seagrass bed area	yes	annual	no	yes	yes
seagrass condition	yes	annual	no	yes	yes
invertebrates	no	1+years	no	no	yes
intertidal algae	no	seasonal	no	yes	?
saltmarsh area	no	annual	no	yes	yes
bacteria	yes	monthly	yes	?	yes
animal kills	some	when occurs	yes	yes	yes
toxicants	some	determined annually	yes	no	yes
shoreline position	no	?	?	yes	yes

Monitoring in relation to oyster kills in the Bay

The monitoring program recommended above is for monitoring the general health of Georges Bay. It does not specifically address monitoring in relation to oyster mortalities in the Bay. This is a complex issue, which has been comprehensively addressed by Percial (2004). Environmental data collected to date do not suggest any potential cause of these mortalities. The fact that only oysters are regularly dying in

Moulting Bay and not other molluscs or finfish or not on the oyster lease near the barway suggests that it is an issue specific to oysters or to Moulting Bay, or both.

As a consequence two research programs in relation to oyster mortalities are recommended:

1. Experimental trials on oyster survival in simulated environmental conditions of different salinities, temperatures, suspended solids, and potential pollutant chemicals such as herbicides, pesticides and the naturally occurring turpines, and various combinations of these parameters. Trials on survival of oysters under different combinations of environmental variables and handling procedures are also recommended These trials would be ideally conducted on site using water entering Georges Bay from Georges River and sediments from Moulting Lagoon.

   As Moulting Lagoon can be highly turbid at times, it is possible that chemicals are attaching to sediment particles and being resuspended in sufficient quantities to impact on the oysters. If possible the above trials should include suspended solids being deposited in the estuary during flood events.

2. Sampling for potential pollutants during flood events. It is particularly important to collect water samples for analysis from the first flush of flood waters into the Bay, preferably sampled at hourly intervals in the initial flood waters, and then every 4-6 hours during the next 24 hours, followed by every twelve hours depending on the size and duration of the flood. As analysis for pollutants such as herbicides and pesticides is very expensive, it may not be feasible to analyse all samples. These should be carefully subsampled to cover the various time periods and more analyses conducted if the results indicate critical times for pollutants entering the Bay. Because we don't know the important times to sample, it is important to sample frequently so that samples are available for later analysis if required. The main site recommended for sampling is the Bridge site because of the ease of sampling at this site during flood events. Another possible sampling site is the Humbug site.

Other recommended monitoring programs

A comprehensive list of possible indicators for Georges Bay, which was compiled by Greg Dowson, Water Specialist, Environment Division of DPIWE for a joint stakeholder workshop to identify and discuss issues related to the bay, is shown in Table 6. This is based on the three principal PEVs (protected environmental values) that have been recently finalised for Georges Bay. This is a detailed list of parameters that covers multiple potential stressors to the bay. However, it was emphasized that the influence of marine and freshwater mixing on nutrient levels within the bay will be better understood and quantified with further monitoring.

The table lists possible water quality targets based on the limited data available. These values are a starting point against which future data on water quality can be assessed. As more information becomes available it may be necessary to change these targets. The site specific levels in Georges Bay relate primarily to sewage outfall and stormwater monitoring.

Table 6. Possible water quality indicators for Georges Bay compiled by DPIWE

Marine (toxicants)/Estuaries(physico-chemical)							
	ANZWQG 2000 (Marine)						
Parameters	**Protection of Aquatic ecosystem**	**Protection of aquaculture species**	**Recreational - Primary Contact**	**Recreational - Secondary Contact**	**Aesthetic**	**Site Specific Levels in Georges Bay (> 20th%ile <80th%ile)**	**Possible WQTs**
DO(mg/L)		>5					>5
DO % Sat	>80 <110	<100					>80 <100
TSS	<80% of seasonal ambient SS of reference system	<10 mg/L				< 8*	< 8*
pH	7-8.5	6-9	5-9				7-8.5
Temperature (C)	< 2 C change, >20% &<80% of seasonal ambient temp of reference system	< 2 change over 1 hour	15-35			>9* < 18	>9* < 18 and less than 2 C change
NOx (ug/L)	15	NO3-<100 000, NO2- <100				<10, 11, 16	< 15
TN (ug/L)	300	ND				100, 180	<200
TP (ug/L)	30	ND				68,98, 126,276	<150**
PO42-(ug/L)	5	<50				< 11	< 11
NH_3/NH_4^+ (ug/L)	15	<100				10	15
Chl a (ug/L)	4					< 5.5	< 6
Turbidity (NTU)	0.5-10	<5				< 2.8 *	< 3
Visual			- clarity more than 1.6 m (or approx. 6 NTU)		Free from surface films and odour		Free from surface films and odour and a clarity >1.6 m (or approx. 6 NTU)
Faecal coliforms (/100mL)		C	Over the bathing season <150 faecal coliforms, with 4 of the 5 samples taken at regular interval not exceeding one month <600/100mL	Over the bathing season <1000 faecal coliforms with 4 of the 5 sample taken a regular interval not exceeding one month <4000/100mL			Median not exceed 14 MPN/100mL with no mopre than 10% of samples exceeding 43 MPN/100mL)
Enterococci (/100mL)			Median over the bathing season of less than 35 enterococci/100mL with max number in any one sample 60-100 orgs /100mL	Median over the bathing season of less than 230 enterococci/100mL with max number in any one sample 450-700 orgs/100mL			Median not exceed 3 # enterococci/100mL with no more than 10% of samples exceeding 7-10# enterococci /100mL)
Copper (ug/L)	<1.3	<5					<1.3
Lead(ug/L)	<4.4	<1-7					<4.4
Mercury (ug/L)	0.1	<1					0.1
Zinc (ug/L)	<15	<5					<5
Chlorpyrifos (ug/L)	< 0.009						< 0.009
Chlordane (ug/L)		<0.004					<0.004
PCBs		<2					<2
Biological	No change from natural conditions for frequency of algal bloom or bioaccumulation of contamianants (e.g. organics)						No change from natural conditions for frequency of algal bloom or bioaccumulation of contamianants (e.g. organics)
** Existing discharge and diffuse pollutants elevating the background level. More ambient monitoring is required to set a lower target in the future.							
* derived from Ansons Bay and Great Swanport data							
# arithmetic interpolation from ANZWQO figures							

Yearly reporting mechanism on the condition of Georges Bay

An annual reporting mechanism protocol for reporting to the community findings on the Bay's water quality and implications of findings is listed below. This table lists the environmental variables that have been recommended for a monitoring program of estuarine health by both the Waterwatch Australia Steering Committee and the Coastal, Estuarine and Marine Indicators Working Group in Tasmania. Normally the annual report would be for a calendar year, but the financial year of July 2004 to June 2005 was chosen because substantially more environmental data are available for that period than just 2004.

Report card for Georges Bay: for 12 months July 2004 to June 2005

Parameter	Comments	Ranking*
Temperature	normal	1
Salinity	normal	1
Turbidity	limited data	
Dissolved oxygen	no data, BOD above guidelines at sewage outfall	
pH	limited data, mostly within limits except at sewage outfall	
Chl a	no data	
NOx, NH4, PO4	NOx - few high values especially Bridge site, NH4 - mostly low, no PO4 data	3
TN, TP	TN - sites in Bay occasionally > WQT, Bridge site ≥ WQT; TP - sites in Bay often > WQT, Bridge site low	3
Seagrass bed area	increased since 1990, stable since 2001/02	1
Seagrass condition	baseline data, limited seasonal data, good condition	2
Invertebrates	no data	
Saltmarsh area	no data	
Pest species	no data	
Bacteria	low in estuary, high at Bridge site	2
Animal kills	ongoing low level oyster mortalities, no mortalities of native species	3
Toxicants	no chemicals above detectable limits in water or oyster meat samples	1
Shoreline position	no data	
Other events of note	none	

*Ranking: 1=excellent, 2=good, 3=satisfactory, 4=poor, 5=degraded

The Moreton Bay Catchment Water Quality Management Strategy Team (1998) have developed a Report Card reporting system for stakeholders in Moreton Bay, which is designed to be informative, jargon-free and relevant to the community. Entitled 'The crew member's guide to the health of our waterways', details are available at **http://www.brmbwms.qld.au/healthywater**. This reporting system was adopted for Georges Bay because of its ability to communicate in plain language to the community the status of the health of the bay. Using this criteria, a mark from A to F can be assigned to Georges Bay. An 'A' is the highest, where the area has an ecological system that is productive and is balanced. It is a stable system with strong resilience and high biodiversity. Conversely, a 'F' is a failure, where the natural system is not functioning well and there is little or no biodiversity. It is out of balance and not ecologically healthy.

Using these criteria and information on the severity of degradation in several sections of Moreton bay, it is recommended that Georges Bay is given a 'B' rating, based on the data available. Georges Bay has healthy seagrass beds, nutrient concentrations are mostly low, although can reach high levels on occasions, no toxicants have been observed in water or oyster flesh samples and bacterial levels in the estuary are low.

However, some nutrients and bacterial levels in the Georges River entering Georges Bay are high and stormwater outfalls have BOD and pH values outside the guidelines. The ongoing mortality of farmed oysters in Moulting Bay is also cause for concern.

A more precise classification of the health of Georges Bay would be possible if more data on recommended environmental parameters were available.

Response protocol for adverse water quality results

It is suggested where adverse water quality conditions are identified the Break O'Day Council should coordinate collection of data which is required to be notified as soon as possible and records maintained by Council of such reports. Depending on the type and severity of impact, the Council should then notify the poor water quality conditions to the relevant section of DPIWE.

It is suggested that Council and DPIWE, through their water quality partnership arrangement, coordinate any action required as a result of the adverse conditions and notify affected people in the community. This should include mechanisms to investigate the source of adverse conditions and if this can be identified, instigate remedial actions.

Linking information between state WQ management systems

There currently exists no formal mechanism for linking water quality information for Georges Bay between the various State water quality information management systems such as TSQAP, DPIWE, Council, Northern NRM. This is likely to change in the near future as a draft Memorandum of Understanding between DPIWE and the Break O'Day Council for the co-ordination of water monitoring activities and data sharing for the Break O'Day municipality was prepared and circulated in September 2005. DPIWE is also proposing to negotiate at a future date with other organizations which collect water quality data, such as Forestry Tasmania, Hydro Tasmania and

TSQAP, to make these data more available to other stakeholders, such as local councils and community groups. The monitoring programs under negotiation are for freshwater; however, monitoring of Georges Bay should link with these co-ordinated activities and the centralized database.

The State and Regional NRM committees will also be setting targets for water quality and to regularly evaluate progress towards those targets. It is recommended that NRM North is approached to provide support to establish formal reporting links between the different providers of water quality data for the Georges Bay and to establish a monitoring program. This requirement for linking of different data sources is not specific to Georges Bay as similar linkages are required across much of Tasmania.

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APPENDIX 1

DATA COLLATED FOR GEORGES BAY WATER QUALITY MONITORING PROJECT

TSQAP

Environmental Monitoring Data for the Moulting Bay Growing Area

- Long-term monitoring program measuring environmental variables such as temperature, salinity, tide, wind direction, faecal coliform levels and rainfall (St Helens and Pyengana).
- Dataset extends from January 1983 to the present.
- 23 sites in Georges Bay have been sampled intermittently over this period, with a minimum of five samples per site.
- Data is held by TSQAP.

Monitoring of Algal Species in Moulting Bay

- Database of algal species found in Moulting Bay over a sampling period from July 2001 to March 2005.
- Includes a number of full counts of both potentially toxic and benign algal species.
- Samples collected from sub-tidal and intertidal regions around Moulting Bay.
- Data held by TSQAP.

Triennial Review of the Moulting Bay Growing Area

- Reviews that provide an update of analysis on the most recent data for the Moulting Bay shellfish growing areas.
- Two triennial reports have been completed, in 2000 and 2003.
- 2003 review incorporates a summary of the environmental data and potentially toxic algal species in Moulting Bay.
- Reviews are held by TSQAP.

Management Plan for the Moulting Bay Growing Area at St Helens (April 2003)

- Summarises critical levels of rainfall and salinity to trigger closure of farms within a zone.
- Includes procedures for reopening a marine farming zone after closure.
- Management plan held by TSQAP.

Annual Growing Area Data Evaluations for Moulting Bay

- Reports summarises salinity, rainfall, faecal coliform and marine farm status on an annual basis.
- Incorporates results from testing of heavy metals, pesticides and herbicides in oyster meat.
- Also includes annual biotoxin monitoring results.
- Have been completed annually since 1992.
- Reports held by TSQAP.

BREAK O'DAY COUNCIL

Recreational Water Quality Reports

- Annual water testing for thermotolerant coliforms and enterococcus levels over the summer period.
- Sites within the Georges Bay area include O'Connors Beach, Steiglitz Beach and Beauty Bay.
- Water quality tested annually over the summer period.
- Reports held by the Break O'Day Council.

Stormwater Sampling

- Sampling occurred intermittently throughout 2001.
- Stormwater monitoring sites included Kirwan Beach, Lawry Heights and Jason St outfalls.
- Samples were analysed for total coliform levels.
- Data is held by Break O'Day Council.

Sewage Outfall Sampling

- Monitoring of the St Helens sewage outfall conducted on a monthly, three-monthly and six-monthly basis.
- Biological oxygen demand (BOD), non-filterable residue (NFR) and faecal coliform monitored monthly.
- Conductivity, pH and dissolved oxygen monitoring three-monthly.
- Oil and grease levels monitored six-monthly.
- Data held by Break O'Day Council.

Pesticide/Herbicide Sampling

- Samples were taken on a monthly basis from July '04 to June '05.
- Sampling was carried out at two sites – the offtake point on the George River and post treatment water from the St Helens Town water supply.
- The samples were tested for a range of agricultural and forestry chemicals.
- Data available on the Break O'Day Council website.

Integrated Local Area Plan – Project report 1996

- Provides a background to Georges Bay, including a social demographic profile, infrastructure and an assessment of management and planning.
- Report held by Break O'Day Council.

TAFI

Physical & Chemical Parameters of Several Oyster Growing Areas

- A technical report providing environmental information on Georges Bay.
- Bathymetry and hydrodynamics, including flushing rates were examined in detail.

- Five study sites were sampled monthly (Marine, Redflash, Lord's Point, Humbug & Mast) from April '93 to February '94.
- Temperature, salinity, chlorophyll a, NO_X, NO_3, NO_2, PO_4 & SiO_4 were measured at each site.
- There were also twelve intensive sampling sites around Moulting Bay for 24 hour, daily and weekly sampling.
- Data held by TAFI.

Survey of Undaria pinnatifida in Georges Bay
- Survey conducted on 4th August 2002.
- Quantitative estimate of the density of plants along three major transects at Lord's Point, midway between Lord's and Humbug Point and Humbug Point.
- Qualitative surveys (presence/absence) were undertaken at marinas, slipways and boat ramps within the Bay.
- Any other introduced marine pests were noted.
- The report is held at TAFI and DPIWE.

Distribution of Feral Pacific Oysters
- This survey includes the distribution and abundance of feral Pacific Oysters in Georges Bay as a snapshot during the spring-summer of 1999/2000.
- The report is held at TAFI.

Assessment of Inshore Habitats for Life-History Stages of Commercial Finfish Species
- A comparison of the abundance and distribution of commercial fish species associated with seagrass (*Heterozostera tasmanica*) as opposed to unvegetated sites in Georges Bay.
- Four sites were sampled (Moulting Bay Nth, Moulting Bay SW, Steiglitz Bch & McDonalds Pt) using beam trawl and gillnets.
- Sites were sampled seasonally between February '95 and February '96.
- Data held by TAFI.

Effects of Shellfish Farming on the Benthic Environment
- Includes data on the current speed & direction, sediment particle size, sediment deposition, redox, sulphide, organic carbon, turbidity and benthic infauna of an oyster lease in Moulting Bay.
- Data was collected in January and February 2000.
- Report is held at TAFI.

Classification of Tasmanian Estuaries and Assessment of their Conservation Significance using Ecological and Physical Attributes, Population and Land Use
- Provides information on the benthic infaunal community of Georges Bay.
- Also examines physical characteristics of the catchment and estuary in comparison to other Tasmanian estuaries.
- Benthic sampling occurred in November 1996, where three transect lines were run perpedicular to the shore, with two replicate core samples taken from five points down the transect.
- Report is held by TAFI.

DPIWE

Oyster Health in Georges Bay: Collation and analysis of data (Percival, 2004)

- A report providing a review of data and information relating to oyster health in Georges Bay, including hydrology, environmental factors and industrial, agricultural and urban influences.
- Identified potential factors that could influences oyster health.
- Made recommendations for future investigations.
- Report is available on the DPIWE website.

Continuous Water Quality Monitoring Station

- Situated at Priory on the George River.
- Flow readings hourly from November 2004 until the present.
- Also samples total phosphorus, dissolved phosphorus, dissolved oxygen, total nitrogen, ammonia, nitrates, conductivity, turbidity, pH and stream level on a monthly basis since November 2004.
- Data held by DPIWE.

George River Water Quality Data

- Data summary of DPIWE water quality monitoring on the George River at the St Helens water supply intake.
- Parameters measured include temperature, conductivity, pH, colour, suspended solids, filt, dissolved oxygen, copper, magnesium, nitrite, ammonia, orthophosphate, phosphate and coliforms.
- Data was reported as averages.
- Data summary is available from WIRED on the DPIWE website.

George River Stream Gauge Data

- Includes site descriptions and stream flow data.
- Stream gauges at two sites – George River at St Helens water supply intake and Ransom River at Sweets Hill.
- Stream flow data for the George River recorded intermittently from April 1968 to October 1990.
- Stream flow data for the Ransom River recorded intermittently from February 1983 to the present.
- Data summary is available from WIRED on the DPIWE website.

Pesticide Monitoring of the George River

- Statewide monitoring program including a site on the George River at the St Helens water supply intake site.
- Sampling occurred on the 4th of February 2005, when the George River was in flood.
- A range of agricultural, industrial and forestry chemicals were tested for.
- Data is available on the DPIWE website.

Review of the Scammell Report: Aerial Spraying in the George River Catchment

- Includes summaries of pesticide monitoring data collected by the River Health Program in the mid-1990's.
- Review available from the DPIWE website.

Draft Water Quality Targets for St Helens Sewerage Outfall

- Includes potential targets for environmental variables including dissolved oxygen, temperature, pH, heavy metals, turbidity, chlorophyll a and coliform.
- In draft form only.
- Held by Environmental Branch, DPIWE.

Rice Grass Management Strategy

- Includes information on the nature of the infestation, potential impacts to the region, and management action.
- The plan will be reviewed in 2006
- Available from the DPIWE website.

AUSRIVAS

Monitoring of the George River Catchment Area

- Six sites were monitored, being George River at Pyengana, Nth George River at the Tasman Hwy, Sth George River at St Columba Falls, Groom River at Anchor Rd, Powers Rivulet at Terryvale Rd and the Ransom River at Murdochs Rd.
- Various sites within the catchment were monitored intermittently from 1994 to 2004 in the spring and autumn months.
- Riffle and edgewater habitats monitored for temperature, conductivity, turbidity, dissolved oxygen and pH.
- Live macroinvertebrate picks were also conducted at each site with taxa identified to family or sub-family level.
- Data held by DPIWE.

NATURAL HERITAGE TRUST REPORTS

North-East Rivers Environmental Review, including Georges Bay & Catchment (Koehnken, 2001)

- A review that includes a brief summary of factors affecting water quality of Georges Bay and catchment area.
- Statistics on industrial operations, aquaculture, wastewater discharge quality and past mining operations.
- Community identified water quality issues within the catchment.
- Report available from RiverWorks, DPIWE.

Ecosynthesis - Lower George Rivercare Plan (Sprod, 2003)

- A report that provides information on the geomorphology, flora, fauna, water quality and water quantity of the George River.

- Included qualitative analysis of sediment deposition in the Holocene delta using aerial photography.
- The majority of data is drawn from DPIWE and the St Helens community.
- Provides recommendations for future management.
- Report available from the Lower George Landcare Group, St Helens.

WATERWATCH

Water Quality Monitoring on the George River & Tributaries

- George River was monitored over a time period from Feb ’98 to Dec ’01.
- Variables measured were mainly pH, temperature and turbidity.
- St Helens Treatment Plant on Reserve Rd was the most common monitoring station.
- Seven other stations along the George River (+ Nth & Sth George) were monitored intermittently or once-off.
- Groom-Ransom Rivers were monitored over a time period from Aug ’98 to Nov ’02.
- Main variable measured turbidity, but temperature, pH, phosphorus, nitrogen, conductivity, dissolved oxygen and E. coli were also measured sporadically.
- The Groom River at Ransley’s river flat site, and the lower reach of the Ransom River (above a Forestry Tas plantation) were the most common monitoring stations.
- Sixteen other stations along the Groom & Ransom Rivers were monitored intermittently or once-off.
- Several smaller water bodies around Georges Bay, including Medea Cove and Moriarty, Windmill & Jock’s lagoons, have also been sampled infrequently by Waterwatch.
- Data held by Dorset Region Waterwatch.

ST HELENS HIGH SCHOOL

St Helens Water – Bacteria & Heavy metals

- Three study sites were examined, being stormwater (from outlet near Captains Catch Seafood), raw water from the George River (Priory) & treated tap water.
- Water sampled three times during flood and normal conditions.
- Once-off study with sampling occurring in Oct 2004.
- Samples analysed for faecal coliform and heavy metals.
- Data held by Break O’Day Council & St Helens High School.

CONSULTANCIES

Aquenal Pty Ltd – Exotic Marine Pest Survey of Georges Bay

- Includes the results of field surveys undertaken between May and November 2003.

- Georges Bay was surveyed at six sites, with three at wharf and slipway areas, two along the channels and one at the breakwall at the entrance to Georges Bay.
- Sampling included video photography, pile scraping, large cores, small cores, plankton tows and traps, with a range of species sampled for.
- Taxa were divided into three groups – target pest species, non-target pest species and cryptogenic species (unclear if they are native or introduced).
- Final report held by DPIWE.

Aquenal Pty Ltd – St Helens Sewage Treatment Plant Upgrade

- A report including a biological survey and impact assessment of the proposed sewage outfall upgrade site in Georges Bay.
- Surveys conducted 25th-27th November 2003.
- Includes the results of habitat mapping and video surveys.
- Benthic infauna data for duplicate samples collected from eleven sites in the vicinity of the proposed outfall route and discharge locations.
- Incorporates a summary of routine monitoring of effluent parameters (biochemical oxygen demand, non-filterable residue and faecal coliforms) provided by Break O'Day Council for September to November 2003.
- Report held by Break O'Day Council.

Aquenal Pty Ltd – Environmental Monitoring in the Georges Bay Marine Farming Development Plan Area

- Benthic monitoring was conducted as a baseline for marine farming impacts.
- Surveys were undertaken within four zones, being Hodgman's Spit (Lease No 228 & 229), East McDonald's Point (Lease No 230 & 231), Moulting Bay East (Lease No 027 & 144) & South West Pelican Point (Lease No 232 & 233) throughout 1999.
- Samples were collected from sites on the lease boundary and a control site, with duplicate sediment cores taken at each site.
- Cores were analysed for organic content, particle size, redox and infauna.
- Data is held by DPIWE (Tasmanian Marine Farming Environmental Monitoring Report: Benthic Monitoring 1997-2002).

Sinclair Knight & Mertz – St Helens Wastewater Treatment Plant Upgrade

- Development proposal and environmental management plan
- Contains summaries of environmental information collected by DPIWE, Aquenal P/L, TAFI, Greening Australia and Break O'Day Council.
- Includes appendices containing water quality monitoring data conducted by Break O'Day Council for the current St Helens Wastewater Treatment Plant and Georges Bay.
- Appendices also include climate data in the form of averages over a variable number of years.
- Copy of proposal held by Break O'Day Council.

Sinclair Knight & Mertz – Georges Bay Baseline Water Quality Monitoring Program

- Water quality data collected for the ongoing monitoring of Georges Bay to ensure that water quality objectives associated with the proposed wastewater treatment plant upgrade are met.
- Sampling was conducted at four sites being Lords Point, Mast, Compass & Bridge.
- Variables tested for included ammonia, nitrite and nitrate, total nitrogen, total phosphorus and thermotolerant coliform.
- Monthly sampling commenced in November 2004 and is ongoing.
- Data is held by SKM.

ENTox – Critical Review of the Environmental Fate of TBT and its Toxicological Effect on the Pacific Oyster Crassostrea gigas including Georges Bay

- Includes data from the TBT pilot and sampling program run by DPIWE from July 2001 to November 2002.
- Also contains recommendations and conclusions to this study and a critical literature review of the environmental fate of TBT and its toxicological effect.
- Report held by DPIWE.

OTHER SOURCES

Bureau of Meterology – Climate data

- Includes rainfall data for a period dating over 110 years.
- Other climatic data including temperature, humidity and wind speed often recorded for over 30 years.
- Data is available from the Bureau of Meterology website, or by contacting the organisation directly.

Review of the Report by Noller (2003) concerning Tributyltin and Possible Impacts on the Oyster Leases at Georges Bay

- Report by Dr Munro Mortimer reviewing the conclusions made by Dr Noller in his 2003 report to DPIWE.
- Report held by DPIWE.

The Impact of Mining Waste on the Rivers Draining into Georges Bay

- Report examining the impact of mine tailings on rivers in the George Bay catchment area.
- Detailed reconnaissance of the catchment area and historical data undertaken.
- Discussion of the geomorphic impacts of increased sediment loading.
- Report found in Brizga, S. & Finlayson, B. 2000. *River Management: The Australasian Experience*. Chap. 7. Bird, J.F. *The impact of mining waste on the rivers draining into Georges Bay, Northeast Tasmania*. pp151

Appendix 2

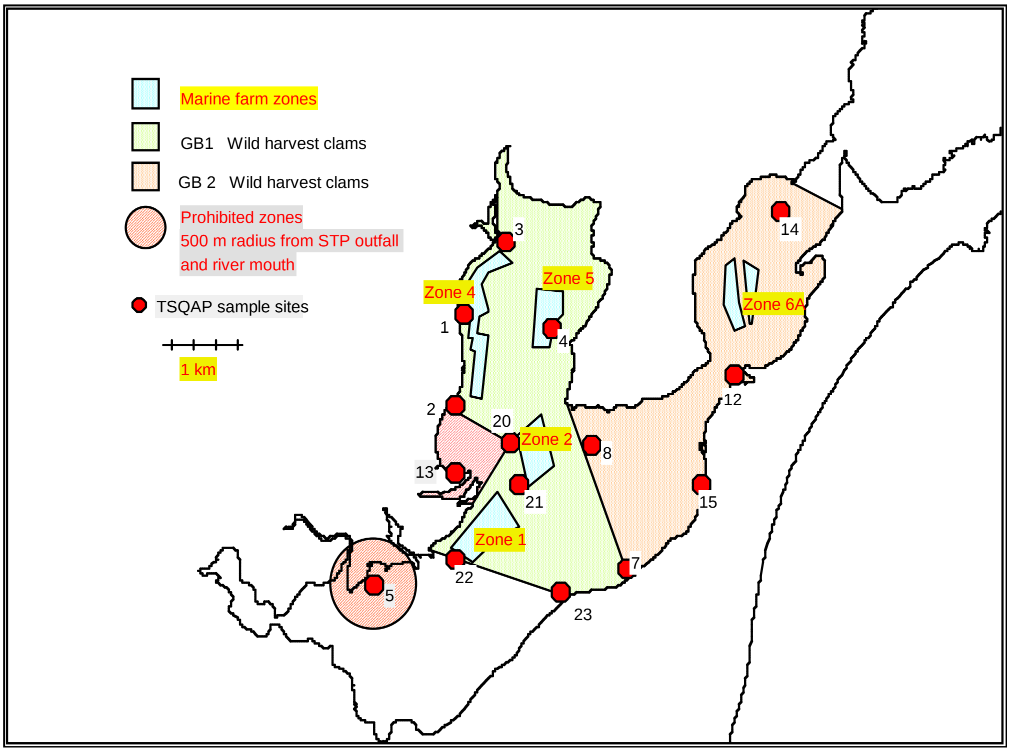

Figure 26. TSQAP sampling sites in Georges Bay

Appendix 3

ANZECC WATER QUALITY GUIDELINES – AQUATIC ECOSYSTEMS

	Chl a µg L^{-1}	TP µg L^{-1}	TN µg L^{-1}	NO_x µg L^{-1}	NH_4^+ µg L^{-1}	DO (% saturation)		pH	
						Lower limit	Upper limit	Lower limit	Upper limit
Upland River	NA	13	480	190	13	90	110	6.5	7.5
Lowland River	5	50	500	40	20	85	110	6.5	8.0
Estuaries[a]	4	30	300	15	15	80	110	7.0	8.5
Marine	1	25	120	5	15	90	110	8.0	8.4

a = These values were ascertained without using Tasmanian estuarine or marine data – a precautionary approach should be adopted when applying these default trigger values.

METALS & METALLOIDS	**Trigger values for freshwater (µg L^{-1})**				**Trigger values for marine water (µg L^{-1})**			
	Level of protection (% species)				**Level of protection (% species)**			
	99%	**95%**	**90%**	**80%**	**99%**	**95%**	**90%**	**80%**
Aluminium pH >6.5	27	55	880	150	ID	ID	ID	ID
Aluminium pH <6.5	ID	ID	ID	ID	ID	ID	ID	ID
Arsenic (As III)	1	24	94	360	ID	ID	ID	ID
Cadmium	0.06	0.2	0.4	0.8	0.7	5.5	14	36
Chromium (Cr III)	ID	ID	ID	ID	7.7	27.4	48.6	90.6
Chromium (Cr VI)	0.01	1.0	6	40	0.14	4.4	20	85
Cobalt	ID	ID	ID	ID	0.0005	1	14	150
Copper	1.0	1.4	1.8	2.5	0.3	1.3	3	8
Iron	ID	ID	ID	ID	ID	ID	ID	ID
Lead	1.0	3.4	5.6	9.4	2.2	4.4	6.6	12
Manganese	1200	1900	2500	3600	ID	ID	ID	ID
Mercury	0.06	0.6	1.9	5.4	0.1	0.4	0.7	1.4
Nickel	8	11	13	17	7	70	200	560
Silver	0.02	0.05	0.1	0.2	0.8	1.4	1.8	2.6
Tin	ID	ID	ID	ID	ID	ID	ID	ID
Tributyltin	ID	ID	ID	ID	0.0004	0.006	0.02	0.05
Zinc	2.4	8.0	15	31	7	15	23	45

PESTICIDES & HERBICIDES	**Trigger values for freshwater (µg L^{-1})**				**Trigger values for marine water (µg L^{-1})**			
	Level of protection (% species)				**Levels of protection (% species)**			
	99%	**95%**	**90%**	**80%**	**99%**	**95%**	**90%**	**80%**
2,4-D	140	280	450	830	ID	ID	ID	ID
Atrazine	0.7	13	45	150	ID	ID	ID	ID
Chloropyrifos	0.00004	0.01	0.11	1.2	0.0005	0.009	0.04	0.3
Fenitrothion	0.1	0.2	0.3	0.4	ID	ID	ID	ID
Glyphosate	370	1200	2000	3600	ID	ID	ID	ID
Hexazinone	ID	ID	ID	ID	ID	ID	ID	ID
MCPA	ID	ID	ID	ID	ID	ID	ID	ID
Metsulfuron	ID	ID	ID	ID	ID	ID	ID	ID
Simazine	0.2	3.2	11	35	ID	ID	ID	ID

ID = Insufficient data to derive a reliable trigger value.